THE

FOUNDRY TRADE JOURNAL

WITH WHICH IS INCORPORATED

THE IRON AND STEEL TRADES JOURNAL.

VOL. 32. Thursday, October 15, 1925. No. 478.

PUBLISHED WEEKLY.

Subscription Terms: 15s per annum.
Foreign and Colonial, 17s. 6d. per annum.
All Subscriptions are payable in advance.

All communications to be addressed to the Editor, or to the Publisher, as the case may be, of

THE FOUNDRY TRADE JOURNAL,
BESSEMER HOUSE, 5, DUKE STREET, ADELPHI, LONDON, W.C.2.

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Forthcoming Events.

OCTOBER 17.

Institute of British Foundrymen (Lancashire Branch, Junior Section):—Presidential address by R. W. Stubbs; also "Moulding a Water Jacketed Cylinder," Paper by J. G. Robinson.

OCTOBER 20.

Manchester Geological and Mining Society:—Ordinary meeting at Manchester.

Institute of Marine Engineers:—Meeting in London. Address by the President.

OCTOBER 21.

Manchester Metallurgical Society:—Ordinary meeting at Manchester. "Modern Grey Iron Foundry Practice," Paper by H. J. Young, F.I.C.

NOVEMBER 23 to DECEMBER 5.

Shipping, Engineering and Machinery Exhibition at Olympia.

THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN; THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION, AND THE FOUNDRY TRADES EQUIPMENT AND SUPPLIES ASSOCIATION.

Institute of British Foundrymen.

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Foundry Trades Equipment & Supplies Association.

Secretary: K. S. Bridges, Avenue Chambers, Southampton Row, London, W.C.1.

The Problem of Research.

By far too great a proportion of the research work turned out in all countries to-day is of the type which the average intelligent third- or fourth-year student would carry out if sufficient money were placed at his disposal, and far too little is of the character which the managing director would institute if he had the time at his disposal. The ideal can only be reached at great expense, as it involves a private research organisation working in close co-operation with the directorate. The co-operative research movement can be improved by a closer co-operation between subscribers and the director of research; the provision of data for use by the private worker, and the ruling out of all problems the solution of which does not materially advance the science for which the Association exists. The research work which would be undertaken by a director if he had the time available would be, nine times out of ten, confined to the field in which he had already some special knowledge, and the results hoped for would place him in a more favourable position than his competitors for obtaining lucrative business. If he is organised both privately and co-operatively for research, the amount of extra work to achieve his own particular object should be minimised. Research work must have a definite commercial object in sight, and if, like the over-enthusiastic company promoter, he has an exaggerated conception of the prospects of his work, so much the better.

A common mistake amongst a certain class of research worker is to criticise too severely the work of the private worker in industry, because the latter carries inherently several disadvantages. Primarily, he may not, on account of his position, be able to say as much as he would like; he obviously has not the variety of apparatus at his disposal as has a national or co-operative organisation. However, on the other hand, he has a deeper appreciation of mass effect and the advantage of repeated practical confirmation or refutation of expressed theories. Scathing criticism of his work or conclusions may impair his relationship with his directorate. As this position has arisen a lessened participation in technical discussions by those in private service is definitely noticeable, and this is greatly to be deplored, as it helps to divorce the academic research worker from industry. Our American contemporary, "The Iron Age," apparently holds a similar belief, as they state:—

"The Society (the American Society of Steel Treaters) was started by practical men, who had developed creditable skill in the mill and forge shop. How will they look on the continued predominance of highly technical papers and such a paucity of the more practical ones as was noticed last week? The Iron and Steel Institute and the Institute of Metals have made some regrettable precedents in this respect and their significance should not be missed by the programme makers of this vigorous American organisation. There is research and research. But much of it is of limited appeal, and therefore has little claim on the time of a convention set for the advance on practical lines of so high and indispensable an art."

As we are solely actuated by a desire to promote the welfare of the metallurgical industries we hope that no one will interpret the above as an attack. We are full of admiration for the work achieved by British research workers in the metallurgical fields, and are only pleading for a truer alignment of their thoughts with those who have at the present time to foot the bill.

Institute of British Foundrymen.

LANCASHIRE BRANCH.

The Lancashire Branch held its first meeting in the current session on Saturday, October 3, at the College of Technology, Manchester, the Branch-President, Mr. J. Masters, in the chair.

PRESIDENTIAL ADDRESS.

The Branch-President delivered his presidential address, which he prefaced by thanking the members for the honour they had conferred on him. He said when he looked down the list of illustrious men who had preceded him in the presidential office, he felt some anxiety as to whether he could maintain the great traditions which they had established, but he would spare no effort himself, and he knew he could rely upon the aid of the Council and members to bring the work of the session to a successful issue. They would have gathered from the syllabus that the Council had been very busy during the summer. Much time and thought had been given to the arranging of a series of lectures which would be both interesting and useful. The subjects were topical, and the members would derive great benefit from listening to the lectures and taking part in the discussion. The manner in which the Council had discharged its task deserved the heartiest thanks.

Quite a lot of useful members had been lost through the continued depression in trade, which they all deplored. He sincerely hoped the marked improvement looked for would not be long deferred. It was with extreme reluctance that the Council decided to accept the resignations, and they were anxious that the loss should be made good. Therefore he appealed to the members to get into touch with men who were eligible and persuade them to come in.

According to the annual report, the Branch was credited with 311 members, but he feared that at the present moment they were not quite so strong as that numerically. Still they had reason to be proud of the position it occupied as being the largest Branch in the Institute, and the only Branch which had made progress during the past year. Another reason for pride was that it was a general comment among the gentlemen who gave Papers during the last session that the Branch meetings in Manchester were the best attended in the Institute, and they also commented appreciatively upon the manner in which the discussions were conducted.

They had to deplore the loss by death of two distinguished members, Mr. R. Kenyon, of Bolton, and Mr. R. Dempster, of Messrs. R. & J. Dempster, Newton Heath, Manchester. The Institute had also lost a very valuable member in Mr. T. Firth, of Brightside, a past-President of the Institute, of whom many Lancashire members had very pleasant recollections in connection with the Convention at Sheffield at which Mr. Firth was elected President.

A diploma had been awarded to Mr. H. Jowett, of Rochdale, a member of the Branch Council, for the Paper he read before the Burnley Section last session. He congratulated Mr. Jowett upon his success, and would add that the Branch Council would be glad to consider any Papers submitted by members, with a view to including them in the syllabus. He was confident that the Branch had sufficient ability to provide for its own needs in the way of Papers, but the members were either shy or had not given serious thought to the matter.

An interesting programme of works' visits was carried out during the summer, and the members derived benefit as well as pleasure from them. Works' visits had also been arranged in connection with the Junior Section. This section had been a great success, and the examination for the John Wilkinson Medal was attempted by 85 candidates. The results had already been made known. The progress of the Junior Section was carefully watched by other Branches, and he understood that the Scottish Branch was proposing to form a similar section in Glasgow. Their Lancashire friends wished them all success, and Mr. Makemson would willingly give them all the help he could.

Mr. R. A. Miles, in moving a vote of thanks to the President for his address, said he knew from his experience of two years in the presidential chair that the post was not an easy one, but there was no doubt as to Mr. Masters' capacity for it. The duty of the members was to support him. They could do that by coming to the meetings, and the very good attendance on the present occasion was a matter for congratulation. There had been a large number of works' visits, and the firms had been very generous in the reception given to the visitors.

Mr. S. G. Smith seconded the motion, and remarked that the President had touched upon a vital matter in his reference to the loss of young members. It was a deplorable fact that through the depression in the foundry industry young men were coming out of employment, and that reacted unfavourably on the membership of the Branch.

The motion was passed unanimously.

The Chairman, in a brief reply, referred to the Presidential address of Mr. G. C. Pierce to the London Branch (Journal, September 17), and remarked that anyone who looked round a meeting of the Lancashire Junior Section would agree that there was a very good class of youths being trained to enter the foundry industry, who were by no means lacking in intelligence.

I.B.F. Notes.

NEWCASTLE BRANCH.

John Surtees Prizes Awarded.

At the first meeting of the session, held in the Neville Hall, Newcastle-on-Tyne, on September 26, prizes were presented by Mr. J. D. Carmichael, the local Chairman of the John Surtees Memorial Scheme, to the successful competitors in the recent examination held in Newcastle, as follows:—1st prize (silver medal), F. Charlton, South Shields; 2nd prize, J. P. Rowan, Jarrow-on-Tyne; 3rd prize, J. E. Harle, South Shields; and 4th prize, E. C. Smith, South Shields.

The winner of the Silver Medal receives also the special prize of McLain's course on semi-steel, presented by Mr. McLain through Mr. R. O. Patterson.

In the course of an interesting address Mr. Carmichael said that he thought the Surtees Memorial Scheme was a great encouragement to young foundry workers, and he hoped there would be an even larger number of candidates when next the competition was held in Newcastle.

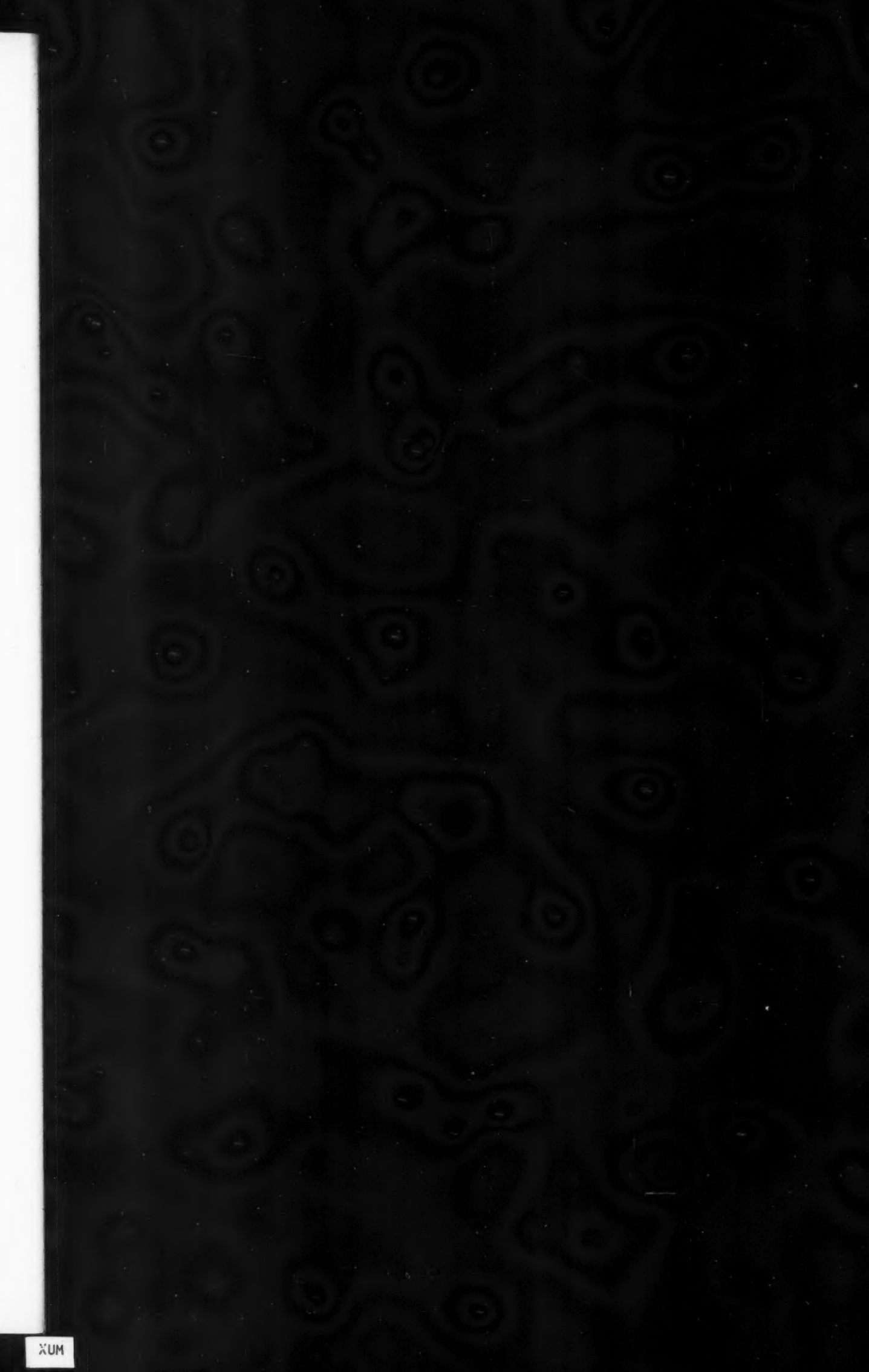
Iron and Steel Production.

The National Federation of Iron and Steel Manufacturers, in their "Statistical Bulletin" for August, report that the production of pig-iron in August further fell to 444,500 tons, compared with 492,700 tons in July and 588,900 tons in August, 1924. It was the lowest monthly total recorded since September, 1922. There were the same number of furnaces in blast at the end of the month as at the end of July. The production of steel ingots and castings declined to 477,100 tons, compared with 590,400 tons in July (the decrease being partly due to the holidays) and 527,500 tons in August, 1924.

According to returns received from 141 identical firms, employment at the end of August showed an increase over July. These firms employed 86,862 workpeople in August, compared with 81,247 in July and 92,537 in August, 1924.

The average earnings of 109,797 workpeople employed in July by 121 firms showed a slight increase over June, and amounted to £3 0s. 11d. per week, compared with £2 19s. 5d. in June and £3 2s. 1d. in May.

Messrs. Frank H. Bate & Company, Platts Works, Amblecote, Stourbridge, are largely extending the foundry.



The Influence of the Temperature upon the Formation of Graphite in Pig and Cast Iron.*

By E. Piwowarsky.

(Communication from the Ferrous-Metallurgical Institute attached to the Technical High School, Aix-la-Chapelle.[1])

Previous Work.

On the question of the influence of the casting temperature upon the formation of graphite and upon the structure and mechanical properties of pig and cast iron, widely divergent views have been advanced in the literature concerned.[2] Hailstone, for example, while employing an iron containing total C, 3.29; Si, 1.9; Mn, 0.34; P, 1.4; and S, 0.1 per cent., established the fact that with increasing casting temperature up to 1,425 deg. C. a distinct diminution occurred in the percentage of graphite contained in the iron. Similar results were arrived at also by Honda and Murakami,[3] who ascribed the increasing formation of carbide to a decreasing evolution of gas in the melt, and, consequently, a repression of the catalytic reaction: $2CO = CO_2 + C$ and $CO_2 + Fe_3C = 2CO + 3Fe$. In contradistinction to these authorities, L. Northcott,[4] employing an iron containing total C, 3.4; Si, 1.4; Mn, 0.9; P, 1.07; and S, 0.09 per cent., recently found that with increasing casting temperature (from 1,210 to 1,410 deg. C.) the graphite content was increased from 2.5 to 2.84 per cent. (with reference to the edge of the samples). As regards the mechanical properties, Oberhoffer and Stein[5] found the casting temperature of 1,240 to 1,250 deg. C. to be the most favourable figure. The composition of the grades of iron employed in this case was approximately as follows:—Total C = 3.3 to 3.7; Si = 1.68 to 1.88; Mn = 0.32 to 1.30; P = 0.57 to 1.02; and S = 0.083 to 0.107 per cent. The graphite content varied from 2.60 to 2.98 per cent. The results as stated by the last-named (Giesserei 10 (1923), p. 424) in respect of the influence of the casting temperature on the formation of graphite may, indeed, be utilised only with reservations, as the selected temperature range (1,170 to 1,310 deg. C.) was too small.

Table II.—*Swedish Pig Iron.*

Heating temperature deg. C.	Duration. min.	Analysis. Total C. per cent.	Graphite. per cent.	Comb. C. per cent.
1250	5	4.00	2.50	1.50
1250	20	3.95	1.40	2.55
1350	5	4.01	1.99	2.02
1350	20	3.91	0.78	3.13
1500	5	3.88	1.28	2.60
1500	20	3.80	2.45	3.35
1650	5	3.82	2.77	1.05
1650	20	3.74	2.24	1.50

Hot Moulds.

Starting from the fact, hardly to be disputed, that the increasing preheating of the casting mould due to the rising temperature of the iron retards the drop in temperature in the interval of the eutectic solidification, a furtherance of graphite formation would have to be expected quite generally from increasing casting temperature.[6] The contrary observations repeatedly made, however, permit the supposition that graphite formation must depend upon at least two mutually opposing circumstances.

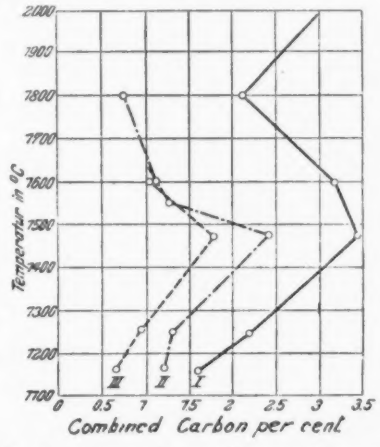


Fig. 1.—Influence of the Heating Temperature of the Melt on the Carbide-Carbon Content.

Table I.—*Result of Test Series.*

Temp. in deg. C.	1153	1250	1475	1550	1600	1810	2010	2200	
Total C % ..	4.01	4.70	5.20	—	5.74	6.00	—	7.96	
Comb. C % ..	1.83	2.19	3.43	—	3.20	2.14	—	3.73	ries I.
Total C % ..	4.01	4.60	4.30	4.25	4.20	3.80	—	—	c_ρ
Comb. C % ..	1.22	1.28	2.43	1.28	1.15	0.73	—	—	Series II.
Total C % ..	4.01	5.10	5.00	—	4.80	—	—	—	
Comb. C % ..	0.68	0.89	1.76	—	1.18	—	—	—	Series III.

The writer was able to observe, times without number, that with the same casting temperature and completely identical metallurgical and technical pre-conditions of casting, one and the same grade of pig or cast iron solidified with varying percentual formation of graphite, when only one variable factor, namely, the preceding maximum heating temperature reached, had been altered. Systematic experiments with regard to this

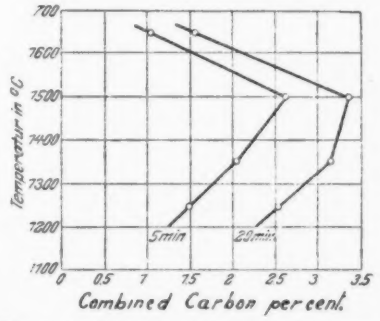


Fig. 2 (as Fig. 1).—Effect of Prolonged Heating Period.

* Translated from "Stahl und Eisen."

[1] Report No. 63 of the Materials Commission of the German Foundrymen's Association.

[2] Hailstone, "Carnegie Schol." Mem. 5 (1913), p. 51; Longmuir, "Iron Age," No. 98 (1916, II), p. 241; "Stahl und Eisen," No. 26 (1906), p. 286; Adamson, "Stahl und Eisen," No. 29 (1909), p. 1577; Cook, "Castings," No. 2 (1908), p. 18; Bolton, "Foundry," No. 50 (1922), p. 436; Smalley, "Engineering," No. 114 (1922), p. 277; and others. *Cf.* Oberhoffer: "Das Technische Eisen," 2nd Ed. (1925), p. 567.

[3] Science Rep. Tok. Univ. No. 10 (1921), p. 273.

[4] Foundry Trade Journal, No. 29 (1924), p. 515.

[5] "Giesserei," No. 10 (1923), p. 424.

[6] *Cf.* the numerous pioneer works by Wüst, Goerens, Gutowski and Schüz in the Transactions of the Ferrous-Metall. Inst. at Aix-la-Chapelle, Vols. 1-4.

phenomenon, therefore, appear to be full of promise.

Experimental Data.

Starting from the assumption that with the magnitude of the temperature range under consideration the general view of the results possibly to be expected must necessarily be clarified to an increasing extent, temperatures up to 1,800 deg. C. and higher were considered for the following preliminary tests. As a basic material a white Swedish wood-charcoal pig-iron of the following composition was used: Total C, 4.01; Si, 0.063; Mn, 0.13; P, 0.019; and S, 0.075 per cent. All the melts were carried out in a Tammann electric furnace, protected against the admission of air, test series I (*cf.* Table I) being conducted in a graphite crucible, series II and III in a magnesia crucible, with the addition of a small quantity of pure electrode carbon. In these first tests the weight of the individual melts was 50 gr. each. During the tests in series II and III the apparatus was placed under a nitrogen atmosphere. The melts were heated up

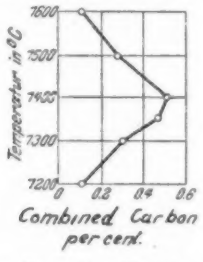


FIG. 3 (AS FIG. 1).—EFFECT OF HIGHER SILICON CONTENT.

to the stated temperature and cooled at exactly 3 deg. per min. (regulation by current-choking), then, about 20 to 30 deg. below the eutectic critical point, dipped with the crucible in water and quenched. The temperature measurement was effected optically. During cooling, there was introduced into the melt, at 1,200 deg. C., a thermo-element pre-heated to exactly this temperature, so as to enable the location of the eutectic critical point to be observed with the aid of the cooling curve. The results of the three series of tests are shown in Table I, as also in Fig. 1. The peculiar characteristic of the curves is the same, irrespective of the method of conducting the test. The curves show that, independently of the kind of test conditions, if only they remain uniform in the individual series:

(1) The eutectic carbide-carbon content increases in proportion to the heating temperature up to about 1,500 deg. C.; and

(2) That, on the other hand, a further rise in the heating temperature, to about 1,800 deg. C., promotes the (eutectic) formation of graphite.[7]

Effect of Prolonged Heating.

With the same Swedish pig-iron a main series of tests, each weighing 100 gr., was now carried out, in magnesia crucibles without the addition of carbon, at temperatures rising to about 1,650 deg. C.; the heating period varying with the temperatures selected for the tests.

Quenching was here effected at 1,000 deg. C. in all cases. Table II and Fig. 2 show the analytical results of these tests. From these it follows:—(1) That, in agreement with the preliminary tests, the critical point is approximately at 1,500 deg. C.; and (2) that below the critical temperature increasing duration of heating acts upon the formation of carbide in the same sense as a rise in temperature.

For the further experiments about 1.2 kg. (2.64 lbs.) of Swedish pig-iron was re-melted in a gas-fired crucible, a small amount of high silicon ferro-silicon being added. The alloy thus obtained was poured in a dried mould to form bars of 20 mm. (0.78 in.) dia. The average analysis of this new alloy was:—Total C, 3.6; Si, 2.4; Mn, 0.13; P, 0.019; and S, 0.075 per cent. Of this iron 120 gr. (4.2 ozs.) each were melted in a Tammann electric furnace, while employing pure alumina crucibles and obviating, as far as possible, the admission of air, the rate of heating being at all times 25 to 30 deg. per min.; the molten product was heated to various increasing temperatures, left for 1 min. at the desired maximum temperature and then cooled at 50 to 60 deg. per min. At 1,050 deg. C. the solidified alloys were removed from the furnace and left to cool further in kieselguhr. The temperature measurement was effected with the aid of a calibrated ardometer. From the cooled melts unexceptionable average samples were taken for the analysis. The results of these tests are given in Table III, as also in Fig. 3. Here, too, the same type of curve as before is to be observed, except that in this case the critical point is approximately 1,400 deg. C., having been, accordingly, lowered about 70 to 100 deg. by the silicon content of about 2.3 to 2.4 per cent.

High Silicon and Prolonged Heating.

In order that the time should be duly considered also in these tests, there was prepared, under the same conditions as those previously outlined, a new test weighing about 1.2 kg. (2.6 lbs.), which differed from the former only by a slightly higher silicon content (2.6 against 2.4 per cent. Si). With this alloy the tests were carried out under the same conditions as those mentioned above except that only three temperatures, comprising the extreme points of the curve in accordance with Fig. 3, were considered, and were each kept at the maximum temperature for 1 min., 5 min., and 20 min. The result is reproduced in Table IV and Fig. 4.

In all three series of tests the critical point is again at the same level, and the contour of the individual curves is the same as in the tests made with the unalloyed Swedish iron (Fig. 2).

Molecular Speed of Reaction.

It was in a certain measure surprising to observe that there evidently exists in all pig or cast iron a definite critical temperature range, on exceeding which the molten iron acquires an increasing tendency to solidify grey. The significance of this fact and the difficulty of finding a suitable explanation for this phenomenon appear to be equally great. If we attempt to explain the diminishing tendency of the iron to solidify grey as the superheating temperature increases, by the gradual disappearance of undissolved graphite constituents alone, we deprive ourselves of the possibility of giving an explanation for the reversal of the curve after the critical reversing temperature has been exceeded. On the other hand, the test results seem to point to a state of equilibrium in two kinds of molecules in the liquid iron which, owing to low speed of reaction, appears only when the duration of heating is prolonged. It is natural to characterise these two molecular possibilities as

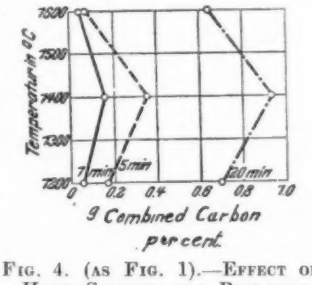


FIG. 4. (AS FIG. 1).—EFFECT OF HIGH SILICON AND PROLONGED HEATING PERIOD.

the carbide and the primary carbon arrangement. If the curve indicating the final state of equilibrium should correspond approximately to the characteristic of the curves[8] in accordance with Figs. 1 to 4, that is to say should acquire an opposite tendency as from a given range of temperature, then one might be inclined to assume that the heat change on the formation of the iron carbide in this range of temperature passes through

[7] By raising the temperature to more than, say, 1,800 deg. C., the tendency to carbide solidification appears again to increase. Two other series of tests, not incorporated in this article, likewise showed at about 1,800 deg. C. a critical point similar to that shown in Fig. 1.

[8] In reality, of course, the critical point is not so pronounced as it may appear in direct connection of the test figures; the drawing of theoretic curves by the indicating points found was, however, discarded.

a zero value, while below this temperature range it would be negative, but above this range positive, so that a rise in temperature in the range of the negative heat change would necessarily lead to the formation of iron carbide, whereas a temperature increase in the range of the positive thermal-change would lead to the dissociation of the iron carbide in the liquid solution, in accordance with the following formula, applying to pure iron-carbon melts:—

$3Fe + C = Fe_3C + W$; in this case:

W = − cal. in the range from about 1,150 to 1,500 deg. C.

W = lim. ± O cal. in the range from about 1,500 to 1,550 deg. C.

W = + cal. in the range from about 1,550 to 1,650 deg. C.

If we adhere to the conception of the co-existence of two kinds of molecules in the molten

TABLE III.—*Silicious Iron.*

Heating temp. deg. C.	Duration of heating. min.	Analysis: Total C. per cent.	Graphite per cent.	Comb. C per cent.	Si. per cent.
1200	1	3.46	3.34	0.12	2.36
1300	1	3.54	3.25	0.29	2.35
1360	1	3.29	2.83	0.46	2.33
1400	1	3.32	2.83	0.49	2.35
1500	1	3.32	3.03	0.28	2.34
1600	1	3.23	3.12	0.11	2.30

highly-carbonised iron, it would have to be assumed, in view of the test-results, that in the melting down of pig or cast iron the iron carbide present at the moment of melting passes into solution as such, while the elementary carbon likewise passes into solution as such at first, but after completed dissolution has the tendency to be converted into the carbide molecular arrangement. To the inertia of this controlling process the fact is, no doubt, to be ascribed, that even when overheated by 50 to 150 deg. an iron that has once solidified grey, retains the tendency again to solidify grey, as the carbon once it has been elementarily dissolved has the power to crystallise out again as such.[9] The graphite thus separated, however, would probably cause the formation of Ledeburite to occur without substantial under-cooling, and this still within the temperature interval of adequate speed of dissociation of the iron carbide.

To prove the assumption of a high degree of inertia (low reaction-speed) in the molecular conversion of the melt, a supplementary series of tests with the alloy containing silicon was carried out, according to the following method: Under the same conditions as those previously stated, the individual melts were heated to 1,600 deg. C., kept at this temperature 1 min., and then cooled to the critical temperature of about 1,400 deg., at which they were left for various periods before being further cooled. According to the hypothesis adopted, a molecular conversion in the direction of carbide formation must then take place with increasing duration of heating at 1,400 deg. C., with the result that the iron thus treated again acquires in an increasing measure the tendency to solidify in accordance with the metastable system. This assumption was confirmed by the test, as may be seen in Table V, which contains the results of tests Nos. 1, 2 and 3.

Each Type of Pig has its own Range.

On the other hand, a melt heated at first to 1,600 deg. C., then cooled to 1,200 deg. C. and at this point heated for increasing periods, would probably exhibit a similar behaviour in a very much lower degree. As will be seen from the results of tests 4 and 5 reproduced in Table V, however, no increase whatsoever occurred in the formation of carbide at 1,200 deg. C. Thus the remarkable observation was made that an iron which has just been brought to the melting point and then, at 1,200 deg. C., heated for an increasing period, acquires a growing tendency to carbide formation, whereas this process apparently does not occur to the same extent when the same iron has acquired through overheating the tendency to the most extensive graphitic solidification —an observation which within the scope of the present test results could no doubt be attributed only to a pronounced passive resistance of the

TABLE IV.—*Silicious Iron.*

Heating temp. deg. C.	Duration of heating. min.	Analysis: Total C. per cent.	Graphite per cent.	Comb. C per cent.	Si. per cent.
1200	1	3.60	3.55	0.05	2.59
1400	1	3.51	3.35	0.16	2.53
1600	1	3.54	3.50	0.04	2.55
1200	5	3.56	3.38	0.18	2.51
1400	5	3.42	3.08	0.34	2.49
1600	5	3.44	3.37	0.07	2.50
1200	20	3.52	2.83	0.69	2.49
1400	20	3.44	2.53	0.91	2.49
1600	20	3.38	2.75	0.63	2.47

transformation process. In accordance with its chemical composition, therefore, every kind of pig or cast iron obviously possesses a definite critical temperature range, on exceeding which it acquires a growing tendency to solidify grey. This observation in connection with the conception of the co-existence of two kinds of molecules in the molten state and the noteworthy influence of the temperature upon their proportionate change, opens up a number of practical possibilities of application, and particularly in cases where all other attempts at explanation had so long proved a failure. A number of cases will now be dealt with, to which the present observations might, perhaps, be successfully applied for elucidation purposes.

TABLE V.—*Silicious Iron.*

Test No.	Max. heating temp deg. C.	Period min.	Cooled to deg. C.	Duration of heating.	Analysis. Total C. %	Graphite %	Comb. C. %	Si. %
1	1,600	1	allowed to cool		3.30	3.17	0.13	2.53
2	1,600	1	1,400	5	3.29	2.95	0.34	2.51
3	1,600	1	1,400	20	3.30	2.52	0.78	2.50
4	1,600	1	1,200	5	3.27	3.09	0.18	2.55
5	1,600	1	1,200	20	3.24	3.02	0.22	2.54

1. In an exchange of correspondence on the subject of "The relations of manganese and carbon in iron and steel"[10] there occurs, *inter alia*, the following communication from C. Stöckmann:—

Example from Ferro-Manganese.

"As far back as April, 1877, when I introduced the ferro-manganese manufacture into Germany, I obtained a pig-iron with graphite precipitating in the centre of the fracture, the manganese content being 17.4 per cent. The silicon content in this mottled iron was 1 per cent. This iron was re-melted in a spiegeleisen cupola. After the iron had been tapped and the cupola had cooled, it was found that the inner wall was completely coated with graphite plates." In a subsequent passage he goes on to say: "The fact that a high manganese pig-iron can exhibit strong graphite formation, even when the silicon content is but slight (1 per cent.), is demonstrated by my tests referred to earlier. In these tests the separation of graphite was due to high temperature, while I prevented the simultaneous production of silicon by means of a highly basic slag."

The fact that an iron with 17 per cent. of manganese could solidify grey is completely opposed to our metallurgical sense and to the existing con-

[9] *Cf.* R. S. Archer, Trans. Am. Inst. Min. Met. Engs. 67 (1922), pp. 445/64, who deals with the possibility of the direct crystallisation of graphite from the melt.

[10] "Stahl und Eisen," No. 3 (1883), p. 197.

ceptions as to the stability of manganese-iron-carbide. If in an iron with 17 per cent. Mn. the molecular constitution of which has been converted into the elementary solution arrangement of the carbon by an excessive rise in temperature, and, notwithstanding the greater stability of the iron-manganese-bicarbide, the reversible transformation into the carbide-molecular with falling temperature has not occurred to a sufficient extent, then this confirms the assumption of the great passive resistance of the transformation and coincides with the observations which had been made in test 4 and 5 (*cf.* Table V).

A similar observation has recently been made repeatedly at the Aix-la-Chapelle Metallurgical Institute. As regards the determination of the oxygen[11] by Oberhoffer's method (heat extraction process), there was used as alloy addition, by way of experiment, a pure white pig-iron—re-melted *in vacuo*—with 6 per cent. Mn. and about 4.2 per cent. C. When the temperature rose too high during re-melting, which could easily happen with a molybdenum vacuum furnace,[12] such as was used in this case, the manganese-iron solidified with extensive formation of graphite.

2.—In experiments connected with the casting of high grade malleable pig-iron from an electric furnace, difficulties are said to have arisen, owing to the fact that a material of this kind with thinner walls has a higher tendency to graphite separation than is usually found when casting from a reverbatory furnace. In this case, perhaps, the local overheating of the iron beneath the arc might have acted in the sense of the present observations.

3.—It is a well-known phenomenon that a pig or cast iron, once it has solidified grey, retains the tendency to solidify grey again to an increasing extent each time it is remelted, so long as it is not kept for a very long time at a moderate superheating temperature. The assumption of a mechanical germ-action in virtue of undissolved graphite constituents is not satisfactory, as like observations were made also with super-heatings of 100 to 150 deg., which should suffice to dissolve the undissolved constituents. According to the present conception the graphite present in the iron would pass into solution elementarily for the greater part, and for lack of sufficient time the transformation into the carbide molecule would not be sufficiently effected. Consider, for example, the tests of Ruer and F. Goerens,[13] who, by repeated heating to about 1,165 deg. C. and cooling at 1.020 deg. C., converted an originally pure white pig-iron (synthetically smelted from electrolytic iron and sugar charcoal) which only exhibited the critical point of the Ledeburite eutectic at 1,146 deg. C., completely into a grey pig-iron which, finally, at 1,152 deg. C., still showed only the thermal change of the graphite eutectic.

On the other hand, it is assumed by F. Sauerwald,[14] in virtue of the unusual contraction during melting of the cast iron that the melting point of grey iron is to be regarded as the temperature for the formation of considerable quantities of iron carbide molecules in the melt.

4.—A fully adequate explanation for the phenomenon of the inverse chill casting has long been lacking. The influence of the oxygen as the determining factor as well as a certain "critical analysis" must be disputed, namely in virtue of extraordinarily comprehensive, hitherto unpublished tests which were carried out at the Aix-la-Chapelle Institute in 1922-23. The observation that an ample addition of scrap to the burden furthers its production, may be considered as unassailable. If the process of the melting down of a burden containing scrap is clearly understood, it will be obvious that, owing to absorption of carbon in the melting zone, there must be produced from the scrap a pure pig-iron free from silicon, but poorer in carbon, and of a temperature which is, indeed, high in relation to its composition, but of a lower degree of super-heating than that which was imparted to the readily melting pig-iron containing silicon already present in the burden. The pig-iron resulting from the scrap and, as it were, "synthetic," will scarcely have been heated above its critical temperature, so that it will have the tendency to solidify in accordance with the metastable system, and will retain this tendency even when the chemical composition is compensated by admixture with the merely re-melted cast iron in the hearth. For the rest, the reports as to the hardening tendency of synthetic pig-iron may probably have originated in connection with the phenomenon described.

5.—Pig-iron produced in the blast furnace with the addition of scrap is said to have the tendency to solidify with a considerable carbide content, the analysis being otherwise unexceptionable, and, even after remelting in a cupola, to tend to hardening of the casting. The prevalent supposition that a difference in the oxygen content must be considered responsible for this undesired phenomenon was found to be incorrect, in virtue of repeated investigations made with iron of these grades at the Aix-la-Chapelle Metallurgical Institute. An explanation on the basis of the present conception might, perhaps, be established in this connection in the same way as it happened in the case of the reversed chill casting.

But even when scrap is not present in the mixture, the iron from particular blast furnaces is said to harden more than an iron of the same composition from other blast furnaces. Without prejudice to the influence—which must be recognised—of the production temperature, the following considered statement would, perhaps, be admissible. We have seen that a silicon content in the casting causes a displacement of the characteristic curves, in the sense that after solidification less free carbide is contained in the iron (*cf.* Figs. 1 and 2 with Figs. 3 and 4); furthermore, that the silicon lowers the critical reversing temperature. Accordingly, two grades of iron uniformly overheated, but with different silicon content, under otherwise like conditions, must also possess a different tendency to graphitic solidification, owing to the different molecular solution-arrangement of the carbon. If ores rich in silica and ores poor in silica are smelted simultaneously in a blast furnace, there may form in bosh and hearth pig-iron grades, locally parallel, which, despite approximately the same production-temperature, have a different molecular constitution in respect of the carbon content, and which, even after thorough mixing in the hearth, will retain micro-locally their individual characteristics, owing to the indicated low speeds of reaction and the high passive resistance. It may also be possible, however, that grades of pig-iron with locally different molecular characteristics may result from excessive fluctuations in temperature before casting (too long changing periods for the air heater).

6.—In the manufacture of thin-walled, high-grade castings, ferro-silicon is added to the burden in order to increase the silicon content, or the well-known E—K briquettes, containing silicon, are employed. The adoption of this method is due *inter alia* to the observation that a cast iron silicised only in the ladle has a less tendency to solidify grey, even when the silicon content to be sufficiently high. Otherwise, indeed, it would be simpler to produce in the cupola furnace a low silicon cast iron and afterwards, in the ladle, bring it to the desired percentage in silicon by the addition, say, of ferro-silicon. The following explanation might, perhaps, be given: Assuming the maximum superheating temperature reached in the melting zone in this case to be about 1,450 to 1,550 deg. C., it will be seen that as regards low silicon iron the critical reversing temperature need not yet be exceeded and that this iron, therefore, still has the tendency of solidifying with a considerable carbide content.

From the great passive resistance of the molecular transformation it follows that the silicon content, which acts in the direction of elementary molecular arrangement, must be all the more active in proportion to the length of time it has been alloyed with the molten iron, *before* incipient solidification, by casting. Hence the danger of the occurrence of hard places in the casting, if the silicon is added only in the ladle, immediately before casting.

Such and similar cases could be added to and discussed at will.

[11] "Stahl und Eisen," No. 45 (1925), pp. 1,341/8 and 1,379/84.
[12] *Cf.* Report No. 51 (1925) of the Materials Commission of the German Foundrymen's Association.
[13] "Ferrum," No. 14 (1916-17), p. 161.
[14] "Zeitschrift anorg. Chem." No. 135 (1924), p. 327.

Some Fundamental Relationships in Cast Iron, Wrought Iron and Steel Manufacture.*

By J. E. Fletcher, Consultant B.C.I.R.A.

Whilst dealing with the many and complex problems brought before the research committees of the British Cast Iron Research Association, the author has found the value of a long experience in iron and steel foundry, blast furnace and wrought iron practice.

All ferrous processes have much in common and the student who wishes to understand any one section of iron and steel works metallurgy is increasingly compelled to correlate the fundamentals of every other section.

In particular the relationships existing between the structural properties of cast iron, wrought iron, malleable cast iron and steel are of fundamental importance.

In Britain the monumental work of Henry Marion Howe is thoroughly recognised and in placing that indefatigable worker alongside our own John E. Stead, every English speaking metallurgist and labourer in the field of ironworks practice would seek to rival his fellow in paying tribute to the memory of the two men who have done most to further the all-round quest of knowledge and advancement in metallurgical science.

The Blast Furnace Product.

At this moment the cast iron, wrought iron, and steel making industries are depending upon pig-iron from the blast furnace as their basis. Direct metal from the blast furnace for castings and through the mixer for open-hearth steel is possibly increasing in favour as a means of producing cheap iron castings and structural steel, but in the manufacture of such castings and wrought iron as must meet the "safety first" conditions of the modern engineer, remelted pig-iron has not yet been superseded.

With the gradual deterioration of reworked scrap the need for good virgin metal in the form of pig-iron of dependable chemical and structural analysis is a necessary corrective, for it must be remembered that methods for desulphurising and otherwise chemically improving the composition of scrap ferrous metals may be at the expense of the physical well being of the structural constituents thereof.

Differences in Pig-Irons of Similar Chemical Analysis.

Two blast furnaces, differing in design and size, using different classes of ores and fuel, with dissimilar driving rates and blast temperatures, may produce pig-iron of like chemical analysis. The results obtained from the remelted pig-iron, whether in the form of iron or steel castings, wrought iron bars or malleable castings may be, and often are greatly different. Can it be expected that the pig-iron produced in a small slow-working furnace, smelting lean ores with cold blast supply, shall have the same physical structure as another iron run from a large hard driven furnace working on rich ores and using a hot blast supply?

During the war period the shortage of hematite iron compelled blast furnacemen to charge steel and wrought-iron scrap with high phosphoric ores and puddling cinder. In many cases the pig-iron analysis approximated to that of well-known and celebrated cold-blast brands of foundry iron, but the physical structure of the semi-steel type of iron was vastly different from the cold-blast variety.

The above matter is of fundamental importance and the author, whilst realising that a pig-iron of given analysis will, in the hands of a capable iron or steel founder, enable iron or steel of desired chemical analysis to be produced, knows from experience that the physical characteristics of irons produced under different smelting conditions are not alike though the chemical analyses may be very similar. The same physical differences are noticeable in the puddled iron produced from two differently smelted irons of similar chemical analyses. In steel production the products obtained from American washed iron and Swedish charcoal smelted irons of similar chemical compositions are unlike in physical properties and parallel differences have been regularly noted in pig-irons for malleable casting processes.

Reasons for the Differences.

There can now be little doubt that the chief differences lie in the following direction:—

(1) Combustibility of fuel and rate of combustion per hr. per sq. ft. of furnace area at level of maximum combustion.

(2) Weight of air supply per lb. of fuel burnt per hr.

(3) Weight of iron produced per sq. ft. of furnace area at maximum combustion level per hr.

(4) Volume of ores or other metal producing portions of furnace burden per cub. ft. of gases at mean temperature between level of maximum combustion and furnace top exit—in terms of volume per sq. ft. of furnace area at maximum combustion level per hr. This being a measure of the ore volume passing through 1 sq. ft. of furnace area per hr. during the reverse passage of 1,000 cub. ft. of gas per hr. through the same area.

(5) Composition and temperature of the gases between level of maximum combustion and furnace top.

(6) Porosity and gas permeability factors of fuel and ore burden, involving lump size of ore and coke and porosity of the individual ore and coke lumps. Where high limestone or other flux additions are made the effect of flux lump size must be taken into account.

(7) Composition and volume of slag produced, in terms of slag weight and volume per sq. ft. of furnace area at level of maximum combustion per hr. Mean temperature of working slags and mean thickness of slag on metal in furnace hearth.

(8) Mean temperature of molten metal when tapped.

(9) Mean time period during which metal is accumulating in furnace hearth between tappings, together with mean depth of metal in furnace hearth.

(10) Character of various ores, etc., in mixtures and their distribution as charged. Reducibility and carburising effect on various ores as affected by porosity or fineness of ores and by velocity of ascending gases and their composition and temperature.

(11) Height of charge column. Stock line to maximum combustion level. Tuyere level to maximum combustion level. Tuyere level to bottom of furnace hearth.

(12) Effect of blast velocity through tuyeres on air distribution. Oxidation in outer ring zones of charge column.

Difference in Blast Furnace Practice.

In this paper it is impossible to do more than touch upon some of the points above mentioned, but, as the problem is of such vital importance to the foundryman, a few brief notes on the differences in blast-furnace practice may be of service. Take, for example, two blast furnaces making foundry iron of 2 per cent. silicon, 1 per cent. phosphorus grade; one more hardly driven than the other, the first making about 6 tons per working hour, the second 3 tons. The blast temperature in the first furnace is taken at 450

* This Paper, which was read before the Syracuse meeting of the American Foundrymen's Association, is one of a series of foundry problems being annually exchanged with the Institute of British Foundrymen. This is the fourth exchange paper presented by members of the British organisation. Mr. J. E. Fletcher is consultant for the British Cast Iron Research Association, and has been actively identified with the development of research in the British foundry and wrought iron industries. He acted as director of the British Cast Iron Research Association during the first two years of its existence, and is now a member of the Council of that Association.

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deg. C. and in the second 535 deg. C. Furnace No. 1 has a hearth 11 ft. 6 in. dia. and a height of charge column (from tuyere level to stock line) of 62 ft. Furnace No. 2 has a hearth 10 ft. in dia. and a height of charge column of 60 ft. The iron content of the ores in No. 1 averages 25 per cent. when calcined, whilst that of No. 2 is 45 per cent. The slag produced per ton of iron in No. 1 is 30 cwt., and that in No. 2, 20 cwt.; the coke consumption per ton of iron smelted being 30 cwt. in No. 1 and 28.5 cwt. in No. 2. From a closer examination of the furnace working the comparative data of Table I have been deduced.

TABLE I.—*Two Blast Furnaces Compared.*

	No. 1 Furnace.	No. 2 Furnace.
(*a*) Iron made per sq. ft. of furnace area at level of maximum combustion (8 ft. above tuyere level in No. 1 and 6 ft. in No. 2 furnace)	100 lbs. per hr.	70 lbs. per hr.
(*b*) Coke burnt per sq. ft. of furnace area at maximum combustion level per hour	150 lbs.	100 lbs.
(*c*) Ore volume passing per hour in terms of cub. ft. per sq. ft. of max. combustion zone area	5 cub. ft.	1.3 cub. ft.
(*d*) Hot gases passing each cub. ft. of ore per hour. Taken at level midway between maximum combustion zone and stock line	6,900 cub. ft. at 510 C.	27,200 cub. ft. at 565 C.
(*e*) Mean velocity of burden descent from stock line to tuyere level ..	3.65 ft. per hr.	3 ft. per hr.
(*f*) Metal rises in hearth at rate of ..	8.5 ins. per hr.	5 ins. per hr.
(*g*) Mean thickness of slag blanket on top of metal in hearth	32 ins.	19 ins.
(*h*) Temperature of throat gases ..	190 C.	315 C.
(*j*) Weight of slag per sq. ft. of furnace area at maximum combustion level per hour	150 lbs.	60 lbs.

In order to visualise what is happening whilst the ore is descending from the stock line to the hot zone in the furnace boshes, that is, the level of maximum rate of combustion, it is useful to conceive the iron oxide which is being reduced to metallic iron as in the form of grains of 1 mm. cube. In Furnace No. 1 the lean ore, 24 per cent. iron content, contains roughly one grain of iron oxide (Fe_2O_3) to 2.5 grains of earthy oxides, the

TABLE II.—*Contract Variations in the Two Furnaces.*

	No. 1 Furnace.	No. 2 Furnace.
Thickness of slag forming oxides covering 1 mm. cube nucleus of iron oxide ..	0.25 mm.	0.10 mm.
Thickness of gas film enveloping the ore grain ..	0.20 mm.	0.15 mm.
Thickness of slag forming oxides covering 1 mm. cube nucleus of reduced iron	0.42 mm.	0.18 mm.
Thickness of gas film enveloping the gangue covered iron grain ..	0.24 mm.	0.17 mm.

mm. cube of iron oxide being coated by an 0.25 mm. thick film of silica, lime, alumina, etc.

When the iron oxide is reduced to metallic iron each, 1 mm. cube of reduced iron becomes surrounded by a jacket of slag-forming matter nearly 0.5 mm. thick.

Similarly in Furnace No. 2, each 1 mm. cube of iron oxide is covered by a thin film of earthy oxides only 0.1 mm. thick. The reduced iron grain is later covered by a film of slag forming oxides 0.18 mm. thick. It is, of course, impossible to assume that such homogeneity of structure exists in the ore mass, but these means of visualisation of the disposition of the iron grains amidst the earthy gangue are helpful to the critical student.

Further, as the measurement of the cubic content of average ore bulk shows that the cubic contents of the voids between the ore lumps is approximately equal to the volume of the solid ore grains the mean thickness of the gas film covering the gangue-covered iron oxide and reduced iron grains is of further interest, as shown in Table II.

In Table I it will be noted that about 4 times the volume of hot gases sweep past each cub. ft. of ore in Furnace 2 than in Furnace 1. Hence, the gas effect must be considerably more potent when in contact with the thin covered iron grain in Furnace 2 than in the case of the thicker covered grain in Furnace 1.

The preheating of the ore and reduced iron during its descent from the stock line to the fusion zone, level of maximum combustion rate, must be greatest in Furnace 2, where the escaping throat-gases are 600 deg. C. This means that iron reduction takes place higher in the furnace stack in No. 2 than in No. 1. It also follows that the carburisation of the iron grains proceeds more rapidly in Furnace 2 because of the more ample gas supply, the grains coming into contact with richer gas at higher temperatures than in Furnace No. 1. The resulting iron will therefore be higher in total carbon content in No. 2 than in No. 1 for, in addition to the richer and hotter gas supply and accompanying higher preheating effect, the burden takes longer to pass through the furnace in No. 2 than in No. 1. The total carbon content of the iron must obviously correspond with the degree of carburisation of the iron grains reduced from the oxides (*i.e.*, the spongy iron) at the time such grains have descended to the temperature level corresponding to the melting point of the carbon-iron alloy produced.

If the ore is rich in iron content and is readily reduced then, if the hot gases produced by burning an excess of carbon per unit area at the level of maximum combustion, per hour, raise the temperature of the preheating zone above that level the fusion level will be raised.

This melting level will be fixed by the proportion of coke to iron in the burden, but will vary with the reducibility of the ores or other iron-yielding ingredient in the burden. Thus hematite ore and furnace cinder may contain equal percentage of iron but the first will require less coke per ton of iron yield and the rates of smelting in the same furnace will differ. The hematite cinder which, as a slag, melts before its iron content is reduced; hence the iron reduced from the cinder is not so highly carburised as that from the hematite. Similarly the iron reduced from a lean ore may descend low into the furnace before it is reduced, carburised and fused, a low carbon iron being the result.

Again, in the same furnace the ratio of coke to ore burden may be greatly different whilst working the same ore. By different rates of driving the iron produced will correspondingly differ in total carbon content, the level of maximum combustion being thereby altered, the rate of carburisation affected and the melting zone level raised or lowered.

All these modifications affect the structural composition of the cast iron produced, even though the chemical composition be little different in irons smelted from such different raw materials as flue cinder and lean oolitic ores.

It is to be feared that many foundrymen are ignorant of the difficulties which confront blast furnacemen engaged in the manufacture of foundry pig-iron, especially in those countries where the composition of ores is continuously varying.

Study of Structural Composition Necessary.

On the other hand the needs of the modern foundryman demand pig-iron of good structural

composition, apart from the chemical composition, which is not the final index to quality. Chemical analysis is a satisfactory index to the constitution of the products of a particular furnace working on definite lines and using burdens of regular composition and physical structure but, from British experience, the chemical analysis does not tell the whole story, wherever a furnace is constantly changing its fuel, ores, flux and rate of driving.

The examination of fracture alone is unsatisfactory, but there is little doubt that the structural analysis of cast iron is reflected in some measure by the fractured casting structure even as examined by the naked eye, for it is an index to that important factor, grain size.

In Britain this question of structural or constitutional composition is now occupying considerable attention and the interpretation of the chemical analysis of cast iron in terms of the constituents is being found to be of considerable value. The author has used this interpretation since 1904 and has found it of great service in correlating the chemical analysis with the microstructure. Since the values for specific densities of most of the constituents of cast iron are now available the composition in terms of the volumetric contents is still more useful.

The application of the method to the composition of pig-iron is capable of giving valuable indications to the causes responsible for the differences in chemical analysis, micro-structure and fracture characteristics. (See Fig. 1).

A typical illustration may be given of the case of two blast furnaces producing foundry pig-iron of similar analysis, the only notable difference in the chemical analysis of the pig-irons being in the relation of the combined and graphitic carbon contents. The pigs were of the same section size and the total carbon content was in each case very approximately the same, 3.3 per cent. Yet in one case the fracture was regularly open grained and in the other close grained.

TABLE III.

The Approximate Chemical Analysis of the Two Pig-irons.

	T.C.	C.C.	Gr. C.	Si.	Mn.	S.	P.
Open grained iron	3.30	0.30	3.00	1.8	1.0	0.08	1.0
Close grained iron	3.30	0.65	2.65	1.7	0.9	0.10	1.0

Structural Composition.

	Open Grained Iron.		Close Grained Iron.	
	Per cent. weight.	Per cent. volume.	Per cent. weight.	Per cent. volume.
Graphitic carbon ..	3.00	9.52	2.65	8.52
Phosphide eutectic (C-Fe-P) ..	14.73	14.45	14.72	14.60
Manganese sulphide	0.22	0.39	0.27	0.49
Pearlite (containing Si and Mn)	2.83	2.58	42.40	39.00
Silico-Ferrite ..	79.22	73.06	39.96	37.39
	100.00	100.00	100.00	100.00

The author has noticed similar differences in the combined carbon content of British hematite pig-irons from the same furnace as influenced by the different cooling conditions during the summer and winter. Apart from the fact that in Britain the wet state of the ore and fuel in winter is conducive to slower reduction whilst the cooler and drier air has the opposite effect, the balance being in favour of higher outputs, it is difficult to trace the higher combined carbon in the winter-made pig-iron to anything but the quicker cooling rate of the iron when run into the colder pig beds.

But in the case chosen for illustration the pig-irons produced in either summer or winter were characteristically different in fracture, as before stated. This is illustrated by Table III.

From this structural composition of the cooled pig-irons it is seen the decomposition of the iron carbide originally present in the molten metal is much more complete in the one iron (0.30 per cent. combined carbon) than the other. The reason for this difference is not explained by differences in the rate of cooling alone, as might be the case when one iron is cast in metal moulds and the other in the customary sand bed, but it is clear that thermal influences must be responsible for the fact, that in similarly constituted sand beds, pigs of similar section are of different hardness. These thermal differences must have functioned within the furnace hearth at the time of casting and before.

The silicon, manganese, phosphorus and carbon contents in the two pigs being alike, it may be concluded that the hearth temperatures in both cases were alike, this contention being supported by the fact that the casting temperatures were noticeably similar.

There must therefore have been a difference in the condition of the carbon in the molten metal either immediately preceding or soon after the casting of the two types of pig-iron. An examination of the probable molten constitution of the hearth metal is of value.

Assuming that the molten metal consists of the 4.3 per cent. carbon and the iron-carbon-phosphorus eutectics in which are dissolved the iron silicide and manganese carbide and sulphide, the molten constituency of the metal is given thus:

4.3 per cent. carbon-iron eutectic, 70.95 per cent. by weight; iron-carbon-phosphorus eutectic, 14.72 per cent. by weight; iron silicide, manganese sulphide and iron (free), 14.33 per cent. by weight.

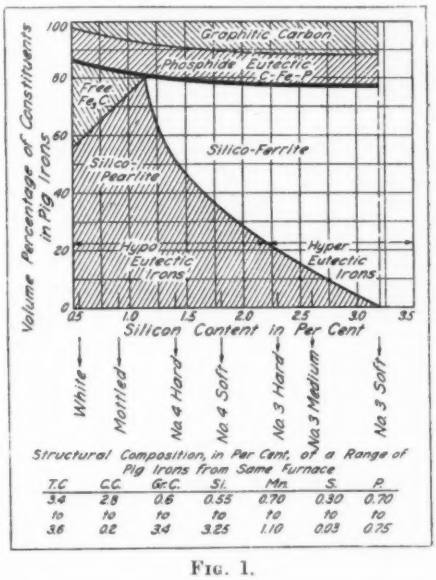

FIG. 1.

Both irons here are therefore hypo-eutectic, a fully eutectic iron of 1.8 per cent. silicon and 1.0 per cent. phosphorus content having a total carbon content of approximately 3.5 per cent.

The carbon content of the iron is of course dependent upon the amount of carburisation received by the iron in its descent through the pre-heating zone and, in the zone of high temperature necessary for the alloying of the iron with silicon, the iron may easily absorb more than 4.3 per cent. carbon and become hyper-eutectic and as such flow into the earth. The action of silicon there is to graphitise the excess carbon, and any metal of this character continues to graphitise during the cooling in the pig beds.

The author considers that this is the mechanism which accounts for the low combined carbon content in some irons. Whenever the carburisation falls short of producing 4.3 per cent. carbon in the primarily melted metal flowing into the hearth the pig-iron is likely to have a lower total carbon and a higher combined carbon content than in an iron produced from metal which has been hyper-carburised in the shaft and boshes of the blast furnace.

In actual practice the carburised streams of metal flowing into the hearth must often be mixtures of hypo-eutectic iron. In the large hearth obstructed by masses of coke perfect diffusion of the heterogeneous components of the liquid metal is inconceivable and some irregularity in the pigs run from the hearth must be expected.

XUM

The Fracture Index.

An intelligent interpretation of the pig fracture, combined with the practice of reading the chemical analysis in terms of the micro-structure, is of the greatest possible value to the foundryman and to the responsible worker in puddled iron and steel manufacture.

The experienced puddler in Britain looks askance when he is asked to puddle a charge of iron possessing what he calls a mixed fracture, which is generally of the nature of an open grained structure in which patches of close grained metal are embedded. One part of the metal comes to grain normally, whilst the other remains steely, and the tendency, unless great care and labour is expended, is for the puddled ball to be uneven in plasticity, composition and weldability.

The author wishes to pay homage to the intelligent puddler from whom, at the furnace side, he has learned much. In no other furnace can so much be learned of the melting characteristics of cast iron. There the effect of hyper-eutectic iron can be clearly seen during melting and refining—the escape of the kishy carbon varying conditions of temperature and furnace atmosphere—the slow "coming to nature" of the iron as compared with a low carbon-hypo-eutectic-iron, and the influence of silicon, phosphorus and manganese on these actions. In the manufacture of wrought iron from pig-iron the quality of the product depends on that of the pig-iron charged. The average chemical analysis of a pig-iron may be apparently satisfactory, but if this is the mean hypo and hyper-eutectic metal, then there is great danger that the latter metal will cause a lack of uniformity in the final puddled ball, the product of the laborious work of a worker who has been too often despised.

To most metallurgists the mean chemical analysis of a pig of iron is sufficient, but this may be the rough average of concentric zones of metal containing from, say, 0.8 per cent. to 0.2 per cent. combined carbon-rings of absolutely dissimilar metal in a structural sense and which, when melted, may produce a molten mass of as heterogeneous a character as the initial structure possessed, and prone to segregatory habits because of the variable condition and distribution of the carbon, especially when this is changing from the combined to the graphitic form or *vice versa*.

Knowing as we do the migratory character of carbon, as shown in the processes of cementation, case hardening, malleableising and graphitisation, is it not remarkable that so little attention has been given to the structural homogeneity of pig-iron and to the means for producing iron of such regular structure as will, when properly re-melted and poured, produce iron castings whose internal architecture shall not need costly methods of heat treatment in order to rearrange a structure which has been primarily confused and segregated in the blast furnace?

The variability of the blast furnace product is recognised by the steel maker where, in mixer processes, the standardisation of the liquid cast iron is of such importance. If carbon did not migrate and if, in large molten masses, phosphorus and manganese diffused regularly throughout the metal, the mixer method might find a wider use in the manufacture of high quality castings; but as mass effect plays such a large part in the segregation of the lighter constituents in iron and steel, the habit of only melting sufficient metal at a time for the making, separately, of large castings, is likely to persist, for sound scientific reasons.

In the realm of the ironfounder and wrought iron worker the problem of obtaining pig-iron direct from the ores free from the effects of intimate contact with the reducing fuel, and hence controllable in the direction of carbon content and homogeneity of structure, has for years been a cherished dream. In Britain longing eyes have been turned towards such sponge iron processes as have given some promise of practical success, and while recognising the technical difficulties attached to mechanically-operated furnaces charged with material in agitation, the long and costly experiments carried out in U.S.A. in particular would seem to indicate that ere long the problem will be solved.

(To be continued.)

Catalogues Received.

Reduction Gears.—Messrs. Crofts (Engineers), Limited, of Bradford, have sent us an advance copy of a 44-page catalogue which describes and illustrates the double helical gears they manufacture. The booklet gives a range covered by standard cases, with the dimensions and powers transmitted at various speeds. In addition to reduction units, other of the firm's specialities are dealt with. The booklet maintains the high standard of publicity which one always associates with the name of Croft.

Hand-Operated Cranes. — Messrs. Herbert Morris, Limited, of Loughborough, have utilised their new publication, Book 104, to make a general appeal as to the suitability of their hand-operated overhead cranes for industrial use. Several pages are devoted to the foundry. We are of opinion that transport being such an important factor in foundry practice, that every bit of information relative to this problem should be carefully filed. At the same time and for the same reason we respectfully suggest that Messrs. Morris should prepare a pamphlet specially devoted to this subject, which would include all types of cranes, runways and floor transport.

Portable Electric Saws.—The B.E.N. Patents, Limited, of 100, Victoria Street, London, S.W.1, who are the sole concessionnaires in Great Britain for the (American) Electro-Magnetic Tool Company, have sent us a folder which describes and illustrates some of the uses of a portable motor-driven portable saw. This should interest the pattern-making side of the foundry industry. We are not sure that British readers will appreciate the assertion the machine is "a wow! and that it packs a wallop like Jack Dempsey." The machine weighs 15 lbs., and is provided with a dust shield. It carries either a 6-in. or 7-in. blade which can easily be replaced.

Welding Rods.—The Suffolk Iron Foundry (1920), Limited, of Stowmarket, after many years of experimenting, have developed and placed upon the market a welding rod to which they have given the registered trade name of "Sifbronze." Its potentialities are described in a recently-published four-page leaflet, which is available for all foundrymen on application. Although the phrase "Welding" has been adopted by those who use this type of material, the process is somewhat different from welding with steel or cast iron. In the new process the article to be welded is only raised to a dull red heat, and quite often it is totally unnecessary to preheat the casting. Sifbronze is stated to be applicable for the welding of all ferrous and non-ferrous materials, except aluminium and its alloys, and is especially efficient when used for malleable iron castings. Before fusion a tensile strength of 32 tons per sq. in. is reported and a high figure is still obtainable after welding. Some practical notes are included in the pamphlet.

Steel Wheels.—Messrs. John Brown and Company, Limited, of Atlas Works, Sheffield, have sent us two pamphlets dealing with the Davis Steel Wheel. Only a few weeks ago we published a Paper on this subject by Mr. W. R. Martin. The one jacketted in blue contains a description of the Davis wheel and follows it up by outlining the economies effected; the technical advantages; the coefficient of adhesion, and finally deals with actual performances on electric railways and tramways. It contains 24 well illustrated art pages. The second (No. 3) confines itself to a description of the process, is smaller (four pages) and is devoid of test results. Both, however, are artistic models of what publicity should be.

THE ADMINISTRATIVE COMMITTEE of the National Union of Manufacturers has decided that a definite campaign of special propaganda of an educational nature shall be commenced by the Union among all classes throughout the country. Such campaign is based upon the referendum to the sub-committee dealing with the scheme, contained in the following resolution, which was passed at the annual meeting of 1924:—"That this meeting reaffirms the policy of the Union that, as a means of relieving unemployment and reducing the burden of taxation, a considered tariff should be imposed on all imported manufactured goods other than food."

Electrically-Produced Blackheart Malleable.*

By F. A. Melmoth (Mappin Medallist).

Malleable iron, particularly in this country, has been, and still is, looked upon by engineers and designers as a material possessing very definite shortcomings. Its use is therefore strictly limited, and its scope of applicability, rather than increasing, is decreasing, mainly owing to the extended use of steel castings and stampings. The most common complaint registered against it is that of irregularity, and one is afraid the justice of the impeachment has very often to be admitted.

The splendid Paper submitted by F. H. Hurren to the Glasgow Conference dealing with whiteheart malleable iron deals most fully with many of the inherent ills of this material, and its whole atmosphere seems to the writer to be a perfect reflection of the position of the malleable industry today, namely, a realisation of the shortcomings in our knowledge of the various reactions involved and an appeal for research. Mr. Hurren's knowledge of his subject being freely admitted, such a Paper calls for the most serious consideration, as it reveals a state of affairs which must be acting as a powerful brake on all possible progress in the industry.

In spite of the work by Dr. Hatfield and others, the fundamentals of malleable cast iron do not appear yet to be fully elucidated, with the inevitable result that difficulty and irregularity in its production are still experienced.

Turning to the blackheart variety of this product, research, more particularly in America, has succeeded in solving many of the fundamentals associated with the material, and the product being more regular, its field of application has correspondingly enlarged, blackheart malleable having become one of America's most important ferrous products.

Some time ago, largely owing to troubles experienced with malleable iron, it became necessary for the writer's firm to consider seriously the production of its own requirements in this material.

Obviously, a decision had first of all to be arrived at as to which type of malleable offered the most promising field for development, always bearing in mind materials and equipment available, together with probable production costs. It was desired, if practicable, to bring existing electric melting equipment into action on this product.

After prolonged investigation into the rival claims of blackheart *versus* whiteheart, it was decided to proceed with blackheart material, and endeavour to try out thoroughly the possibilities of its manufacture in the electric furnace.

The decision was based on the following assumptions:—(1) Under given conditions the production of blackheart malleable is more certain than is the case with whiteheart; (2) the test results available in correct material of either type are of a higher standard in blackheart; (3) the regularity of the product with varying thicknesses of section is more marked in the case of blackheart; (4) the temperature of annealing is lower, and time required less, which spells economy; and (5) the very heavy consumption of annealing pans in the whiteheart process is considerably mitigated by the facts in No. 4 above.

Metal Production.

The manufacture of the necessary metal can be approached from either of two angles, the electric furnace being utilised:—(*a*) Synthetically, by carburising steel scrap, and (*b*) by the direct melting of pig-iron, and its adjustment to the necessary composition.

The cost of pig-iron of the correct type, and the influence of transport charges, rendered method (*b*) one of considerable doubt from an economic point of view. Investigations were therefore primarily confined to method (*a*).

The details of the production of a white cast iron synthetically in the electric furnace are so well known that space need not be occupied in entering closely into them, and the writer proposes to deal only with the control which becomes necessary when such material has to be of a type which can be afterwards malleablised to the blackheart condition.

The fundamental condition is that the iron must be so correctly balanced in its carbon and silicon contents that the after-application of the necessary temperature for the required time will result in the precipitation of practically the whole of the combined carbon as temper carbon, by the catalytic action of the silicon. The material after annealing will then consist of a matrix of silico-ferrite, with scattered, finely-divided and nodular-shaped particles of temper carbon. It should be noted that whilst in the whiteheart variety the malleablising process is directly through the abstraction of carbon by oxidation, no oxidising action is relied upon in the blackheart process. Although a slight surface oxidation of carbon is inevitable during annealing, basically the process depends upon a change of condition of the carbon content, induced by the effect of temperature and time and the silicon content.

This change being a very delicately balanced action, and susceptible in the extreme to variations in conditions, control of carbon and silicon becomes of the utmost importance.

Analysis Sought.

The analysis range found to be most suitable in the hard state is as follows:—Carbon, 2.35 to 2.6; silicon, 0.80 to 1.00; manganese, under 0.3; sulphur, as low as possible, say 0.03; and phosphorus, 0.15 to 0.25 per cent.

The carbon and silicon are, of course, somewhat variable in their requirement, and depend largely upon the average sectional area of the class of work being made. Bearing in mind the essential of a definitely white non-graphitic fracture in the casting before annealing, it is possible, on very light work, somewhat to increase the upper limits of the range given above for these elements.

INFLUENCE OF COMPOSITION.

Carbon.

The tensile strength of blackheart malleable iron is to a large extent inversely proportional to its total carbon content. This is due to the fact of the continuity of the tough ferrite matrix being interrupted to a more or less degree by the particles of temper carbon. It follows, therefore, that to obtain the highest degree of strength the carbon content must be as low as is possible to produce—with the silicon present—a material, after annealing, in which the combined carbon has been almost entirely dissociated from the Fe_3C iron carbide form to free carbon and free ferrite.

To obtain this result it is possible, within reasonable limits, inversely to balance carbon and silicon contents. Thus, with a low carbon-content and a high silicon, or inversely with a higher carbon and lower silicon, the ultimate end would be, within limits, similar.

The point of paramount importance is that no free carbon must exist in the unannealed state of the material, or the resultant product after annealing is quite accurately described technically as "rotten."

Silicon.

The function of silicon appears to be only that of a catalyser. Its presence in definite amounts, somewhat inversely proportional to the carbon, is essential to the decomposition of the iron carbide into free iron and free carbon during the annealing process.

If present in too large a quantity the liability to the precipitation of graphite during cooling from the molten condition is markedly increased. The percentage allowable is also controlled to a considerable extent by the average cross-sectional area of the castings being made, and its amount should vary in inverse direction to the section.

* A Paper read last Thursday before the London Branch of the Institute of British Foundrymen, Mr. G. C. Pierce presiding. The Author is Foundry Manager to Messrs. Lake & Elliot, Limited, of Braintree, Essex.

XUM

Manganese.

It is believed that the *simple* carbide of iron Fe_3C is more easily dissociated into its components by the action of heat, when unaccompanied by a double carbide, such as the double carbide of iron and manganese. The presence of manganese in quantities sufficient to produce appreciable amounts of the double carbide certainly appears to retard annealing, and tends towards the formation of pearlite, the eutectic mixture of iron carbide and iron. This produces a marked inclination in the material towards "banding," a type of defect which will be dealt with later. The presence of a greater amount of sulphur than is normally present in the electric furnace product would probably, by accounting for part of the manganese as manganese sulphide, permit of a somewhat higher upper limit figure. With the very low sulphur existing in electric-furnace white iron, the writer has been unable to detect any real advantage in the use of manganese. If, as is sometimes claimed, it contributes additional strength, it may be because it tends towards the formation of pearlite, a constituent pre-eminently of value in whiteheart, but of dubious benefit to blackheart material.

Sulphur.

This element, if present in appreciable quantities, is decidedly harmful to blackheart malleable. This is on account of its action in tending to stabilise the iron carbide content, which makes its transition to free carbon and free iron difficult by normal methods of annealing.

The percentage of manganese present would doubtless have a modifying action in this direction, but the objections to the latter element previously stated make it advisable not to rely on this action, but rather to keep sulphur content as low initially as is possible and commercial.

Phosphorus.

Up to the limit of 0.25 to 0.30 per cent. no detrimental effect has been directly attributable to this element. The reverse appears rather to be the case, as it has been noticed at times that a low phosphorus content has resulted in annealing being more difficult. It can be assumed, therefore, that up to the limits mentioned, the action of phosphorus is in favour of the easy decomposition of iron carbide into its component elements.

Above these limits the known action of phosphorus on the ferrite becomes noticeable, and the material to some extent loses in tensile strength. The writer would also expect that the capability of the material to resist shock impact would be lessened, but has no figures to offer to confirm this.

Chromium.

This element is one which can be dealt with as an accidental impurity. Its action on iron carbide is well known, and it would therefore never be intentionally added to blackheart malleable iron. If present in appreciable quantities it results in the almost complete retention of the carbon in the combined condition, and annealing is an impossibility. In small quantities its action is to produce in the material a strong tendency to "banding."

The influence of the various elements being accepted as approximately the above, it becomes necessary to decide whether or no the electric furnace was a suitable medium for the production of the material. More definitely, could the electric furnace be relied upon to give the necessary control of composition in order that the elements mentioned would be consistently kept within the essential limits?

The composition laid down was as has been stated earlier.

The writer can say with confidence that this range of analysis can be easily conformed to in the electric furnace. No serious trouble was encountered, and given some experience of electric melting, no fear of serious variations likely to affect annealing need be entertained.

Silicon content being vital calls for special caution. Under the basic slags used there is a tendency for a partial absorption by the slag, which, however, can be counteracted by the usual means of keeping the slags reducing, and controlling the time for which the silicon content is exposed to such action.

Practical Results Obtained.

The metal was found to be fluid, and very sound. No abnormal difficulties of casting arose, and no intricate special precautions in moulding were found to be necessary. The writer is of the opinion that the metal does not demand the amount of feeding to produce a sound casting usually found with cupola-produced metal. It appears to be entirely free from gases likely to produce unsoundness in the casting, and the amount of superheat obtainable in the electric furnace makes the production of light sections a comparatively easy matter. It possesses no undue tendency to crack either during or after solidification, and compared with the cupola product appears very much stronger in the hard cast condition. This latter is quite an important commercial factor, as it reduces appreciably possibilities of fracture in handling before annealing.

Potentialities of Electrically-made Malleable.

Having demonstrated the possibility of the electric furnace being used as a means of producing the necessary iron within the essential limits, the point next arising was the annealing capabilities of the material. The question to be answered was:—Is the material affected in any way by the electric furnace atmosphere, or any possible arc action, which would cause it to resist annealing under ordinary commercial conditions?

An article published by Felton some time ago suggested that in process of manufacture in the electric furnace some unknown condition was set up which caused inexplicable variations to normal behaviour when annealed.

A very painstaking series of experiments had been performed, and as a result it was suggested that it was inadvisable, in the light of present knowledge, to adventure into the field of blackheart malleable iron made in the electric furnace. Bearing in mind, however, the undeniable beneficial effects of electric furnace conditions upon both steel and grey iron, the writer felt that more investigation might prove some physical advantages to be conferred by electric melting. He is unable to explain in any way the variations encountered by Mr. Felton. After making some hundreds of tons of the material, he suggests that no trouble need be experienced if the following fundamentals are adhered to:—

(1) The iron as cast must be entirely free from free carbon; (2) the carbon and silicon must be so balanced in their *relative* proportions as to produce, when annealed, the almost complete dissociation of the iron carbide; (3) manganese should be kept low; and (4) sulphur as low as possible. These points refer only to the metal as such, and further contributory points bearing on the question will be dealt with later.

The writer, having satisfied himself under laboratory conditions that the material would produce correctly constituted blackheart malleable, large enough quantities were produced to bring into action an annealing furnace more nearly of commercial size. The effects of mass action, packing conditions, and so on were then capable of being observed.

It is quite normal to find that conclusions arrived at by laboratory or other small scale investigations are completely upset when the hard facts of bulk production and workshop conditions and appliances come into the equation. Numerous points arose for settlement, principally connected with the following causes:—(*a*) Packing material: (*b*) time required for heat conduction through large boxes; and (*c*) local variations in temperature in the annealing furnace.

The writer proposes, therefore, to deal with these *seriatim*.

Packing Material.

To produce correct blackheart malleable, the packing material is required to be, firstly, of practically a non-oxidising character, secondly, of a degree of fineness sufficient to promote close packing and the elimination of as much as possible of included air spaces, and thirdly, to be not too refractory which would result in a very slow heat conduction through the packed box of castings.

Several materials were used, sand, millscale, and spent annealing ore being the principal ones. The first material, sand, whilst conforming quite well to conditions one and two, fell down very badly in condition three. To produce satisfactory annealing throughout, the time period had to be considerably increased.

The second material, millscale, conforms to requirements two and three, but as received is far too oxidising for use. A defect is produced which is dealt with under defects due to annealing.

The third material, spent annealing ore, gave fairly good results, but in addition to being somewhat too coarse, its condition as received varies from being almost non-oxidising to a state in which it is strongly oxidising, and more suitable for whiteheart practice.

The defects of millscale and spent ore, being due to excessive oxidising capacity, are able to be corrected. Their action upon the carbon of the castings is productive of a continuous reduction of the amounts of active oxide of iron they contain.

When this active oxide is reduced to very small proportions, their action from a decarbonising point of view is almost negligible, and so long as additions of fresh material are very small, no further trouble is experienced. The addition of crushed acid slag considerably reduced the activity of the initial packing material, without seriously lowering its conductivity for heat. The packing the writer is now using, therefore, is a mixture of spent ore, millscale, and crushed slag, to which additions are made as required, in the smallest possible quantities.

Heat Conduction Through Boxes.

The question of conduction through large boxes is of considerable importance. With thermo couples so adapted as to show temperatures of top and bottom of the annealing furnace, the writer was surprised to find how long a period elapses before the bottom temperature comes within reasonable distance of the top. This is undoubtedly controlled to some extent by the nature of the packing, and caused the rejection of sand as a packing material.

In a furnace holding 7 to 10 tons of castings packed in boxes 18 in. sq. a period of 18 to 24 hrs. was often required to approach equilibrium of temperature. It has to be remembered that blackheart malleable is very susceptible to high annealing temperatures, and loses materially in quality by such treatment. It is, therefore, impossible to force the temperature at the top of the furnace in order to aid the bottom.

These remarks obviously lead to the question of furnace design (*c*).

Furnace Design.

Although good furnaces are obtainable, the difficulty of evenly heating the large mass involved, does not appear to have been solved. In the general type most of the heat is admitted at or near the top, at one end, or on two sides. To produce a material showing to the full the real capabilities of blackheart malleable, a very close control of annealing temperature is necessary. The range within which the best material is obtained is not by any means wide, and therefore variations of a local character in the annealing furnace become serious. A type of furnace which suffers to the least extent from unequal heating must therefore be insisted upon.

The formation of temper carbon, upon which fact the whole nature of blackheart malleable is based, takes place slowly and progressively as the temperature falls during the cooling period.

Unless the speed of cooling is coincident with the rate of progression of this change, varying amounts of carbon in the combined form will be carried down to the recalescence point, at which point they become pearlite. Such material will not possess the true characteristics of blackheart, being much harder, and less easily machinable. It will break with a steely fracture scattered over with dots of temper carbon. It is essential therefore that the annealing furnace shall be so constructed as to allow of absolute control of the speed of cooling, in all parts. This speed should approximate to 7 to 10 deg. C. per hr. in the upper ranges, falling to a speed of 3 to 5 deg. per hr. as the temperature approaches 760 deg. C., from which figure down to 690 deg. C. no speed of fall greater than 3 to 5 deg. per hr. is permissible. Such figures call for careful insulation of the furnace particularly in the vicinity of the doors.

The Annealing Process.

The process of annealing is, shortly, as follows: The carbon content, entirely in the form of Fe_3C, or cementite, is taken into solid solution in the iron by retaining at the desired temperature for a sufficient length of time. The period of soaking at the full temperature causes the graphitisation of this solid solution, assisted by the action of the silicon content. This graphitic carbon is then precipitated from solution in the form of temper carbon, as the temperature is slowly and progressively reduced. Temper carbon and graphitic carbon are essentially the same, the difference being one of form. The degree of fineness of the temper carbon is largely a matter controlled by the maximum temperature reached during annealing. The higher this temperature the more the temper carbon particles take the form of graphitic carbon, and as a consequence, the weaker the material. This, of course, is in addition to any weakness contributed by the action of long-sustained high temperature on the ferrite, which becomes more coarsely crystalline, and therefore weaker, the higher the temperature of annealing.

The solution of the iron carbide, or cementite, and the graphitisation of the resulting solid solution take place at a speed which is controlled by the temperature attained during annealing. In order to shorten the annealing process, it might therefore be thought advisable to work at higher temperatures. A consideration of the above points will show, however, that this cannot be done without a corresponding loss in the quality of the material produced.

Defects Due to Annealing.

The common defects, normally due to the annealing operation, are as follow:—(1) Banding, or the production of pearlite in the outer skin of the casting; (2) a coarse crystalline arrangement of the ferrite with consequent loss of strength and ductility; (3) a structure composed largely of pearlite with scattered particles of temper carbon, which is brittle; (4) an angular coarse formation of the temper carbon, with loss of strength and ductility; and (5) a mixed structure of temper carbon and pearlite containing scattered particles of cementite. This structure is hard, brittle, and practically unmachinable.

Taken in the order named, the writer is of the opinion that the reasons for these are as follow:—

Banding.

There are several contributory reasons for this defect, but the main one appears to be an excessive removal of carbon from the outside skin of the casting, during annealing. It has been previously stated in this paper, that the fundamental principle in blackheart malleable is the balancing of the carbon and silicon content in such a manner as to be able to dissociate the iron carbide into free carbon and free iron by the action of heat.

If, with a given silicon content, too low a carbon content were used, normal annealing and cooling would produce, not blackheart malleable, but a brittle steely material, having a structure largely pearlite, with only part of the carbon deposited as temper carbon. It follows, therefore, that a local removal of carbon, from any cause, is liable to be followed by the production, in greater or less degree, of this state of affairs in the part affected.

An oxidising packing material, say containing an excessive amount of active ferrous oxide, would remove carbon from the outer portions of the castings, and bring about this result. A coarse packing, with excessive air spaces, tends in the same direction. The writer would add that this oxidising action is aggravated by a high annealing-temperature, and pearlite bands are frequently due to this error. Another reason, somewhat connected with the one dealt with, but

perhaps open to argument, is believed by the writer to be the following:—

It has been previously stated that in order to produce material as high in tensile and ductility as possible, the carbon content must be kept on the low side, that is, so far as is permissible to produce normal behaviour during annealing. As the result of many experiments, the writer is convinced that some absorption of surface carbon takes place always in commercial annealing, no matter what precautions are taken. He suggests, however, that a compensating action is proceeding during the annealing period. Oxidation can only continue until such time as the gaseous atmosphere of the box of castings becomes largely carbon monoxide, when it ceases entirely.

The cementite being in solid solution at this time, is tending to diffuse, causing a movement towards equilibrium of carbon content between centre and outer portions of the castings.

If the total carbon was originally on the low side, this diffusion may be of an amount insufficient to raise the outer portions to a percentage of carbon capable of being precipitated as temper carbon during cooling. Pearlite formation naturally follows, and the casting possesses a hard outer skin, of varying depths and very difficult to machine. *Per contra*, the original carbon content being on the high side, diffusion is sufficient in quantity to build up the carbon content of the outer skin affected by oxidation, and sufficient is present for temper carbon precipitation to proceed normally.

The steps necessary, therefore, to combat this defect are the use of a packing as little oxidising as possible and fine enough to prevent the inclusion of excessive air in its interstices, a temperature of annealing not too high in an ambition to speed up matters, and a carbon content not forced too low in a laudable but perhaps over-enthusiastic effort to obtain abnormal tensile and elongation results.

Coarse Ferrite.

The coarse ferrite formation is almost entirely due to the use of too high an annealing temperature, although it is possible it may be accentuated by an excessive phosphorus content.

Pearlite and Scattered Temper Carbon.

This structure may be caused by too short a time at full temperature. Graphitisation may not be completed, and part of the carbon exists in the combined form, although the original cast form of the iron carbide may be completely removed. Too rapid a cooling rate also tends towards the same condition, the temper carbon not having a sufficient period during which to form.

Angular Formation of Temper Carbon.

The form taken up by the particles of temper carbon is entirely a function of temperature of annealing. Low temperature and sufficient time produce a nodular, more or less innocuous shape, whilst this form becomes progressively more angular and deleterious in its influence as the temperature increases. This constitutes a further argument against undue haste and the use of high temperatures.

Temper Carbon, Pearlite and Cementite Structure.

This mixed structure is obtained when either temperature or time, or both, have been insufficient. The original iron carbide existing as cementite must be completely taken into solution. In this case all the reactions involved have only proceeded partially, and the material is worthless as it stands. It can, however, in this case be salvaged by a careful second annealing at a reasonable temperature, thus allowing the partial changes to complete themselves.

Physical Test Results.

In correct conditions, where precautions are taken to obviate the various annealing defects above dealt with, a material is produced possessing a remarkably high standard of performance under test. Many hundreds of charges from 30 to 40 cwts. each have been run into castings, and the results obtained from standard test bars, annealed with the castings, carefully logged for comparison purposes. Average results appear to run about 25 tons maximum stress with 14 to 15 per cent. elongation on 2 in., but a considerable number of charges have given results well over 26 tons and 20 per cent. elongation. The maximum figures obtained up to now are 26.9 tons with 28.0 per cent. elongation on 2 in. The general strength of the castings made from the charge represented was abnormal for malleable, and was almost comparable with castings made from mild steel.

It is not claimed that such results can at present be obtained in all instances, even with the most extreme degree of care, but careful investigation as to the causes of these occasional remarkable results should lead to a more complete understanding of their character, and the consequent raising of the average standard.

In all cases where material giving over 20 per cent. elongation has been obtained the total carbon was on the low side, in the neighbourhood of 2.35 per cent., and it has not been found possible to produce results of this nature from material in the higher ranges of carbon, no matter how careful the annealing control. Unfortunately, however, low carbon material is much more susceptible to the production of pearlite bands, from any of the causes previously dealt with, than is the higher carbon material. The solution appears therefore to be the complete elimination of the band-producing condition, so as to enable the general product to be run at the lowest practicable carbon content consistent with a satisfactory behaviour of the material from a casting point of view.

Tensile and elongation properties in blackheart malleable, unlike other metallic alloys, increase or decrease together. In correctly constituted material a high tensile is associated with a high degree of elongation, and a low tensile with a low elongation. This remark refers only to material which can accurately be described as blackheart malleable—that is, an iron carbon alloy in which the whole of the carbon has been precipitated as temper carbon, with a general structure of correctly proportioned ferrite.

Some of the intermediate products due to incorrect annealing, and containing considerable percentages of carbon as pearlite, will, as might be expected, sometimes show unusually high tensile figures, but in such cases elongation is always low.

The anticipated difficulties regarding the constitution of packing materials, and even heating of annealing furnaces, having been overcome, the regularity of the product became very good.

Unusual cases of abnormally high elongation figures, whilst being interesting and offering useful opportunities for research as to their cause, are not the best criterion of the value of a product such as malleable iron. The writer feels sure that the fact of the last 52 charges of metal of 35 cwts. to 2 tons per charge, having given results after annealing which average 25.7 tons per sq. inch with 17 per cent. elongation, will more easily convince members that the product has decided possibilities.

Summary.

To summarise the foregoing, his experiments, coupled with the results now being obtained in practice, have convinced the writer of the following points:—

(1) The electric furnace can be quite successfully utilised for the manufacture of blackheart malleable iron.

(2) That in some degree the beneficial effects of electric melting on steel and grey iron are also operative in the case of blackheart malleable.

(3) That the possibility of the use of a cheap base material, together with a high degree of superheat which reduces the waster percentage, make the proposition quite commercial.

(4) That no detrimental action either by arc effects or furnace atmosphere appears to affect the product and cause difficulty in annealing.

A series of micro-photographs with the necessary description is appended to the Paper, and the writer wishes to express his gratitude to Mr. H. G. Monypenny, chief metallurgist, Brown Bayleys Steel Works, Limited, Sheffield, for his assistance in this respect.

He would also acknowledge with thanks the permission to publish the matter dealt with in the Paper granted by the directors of his firm, Messrs. Lake & Elliot, Limited, Braintree.

One of the Causes of Variations in Rates of Graphitisation of White Cast Iron.*

By Anson Hayes and H. E. Flanders, Ames, Iowa.

The use of any rapid method of annealing white iron in the production of malleable castings essentially amounts to cutting down the factor of safety which is provided by the present long annealing cycle. The use of a greatly reduced annealing period thus necessitates a rather precise knowledge of the factors that cause variations in the rates of graphitisation of white cast irons of normal chemical compositions. Hence this study has been made as a part of a programme whose purpose is to make feasible the commercial use of a greatly shortened annealing cycle.

Recently a commercial concern which has been

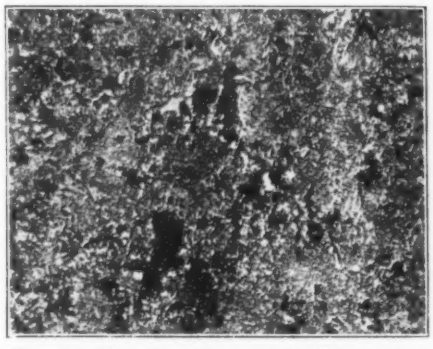

Fig. 1.—Normal Graphitising White Cast Iron Melted and Cooled in Induction Furnace. × 100.

co-operating in this work submitted a sample of white iron whose chemical composition was considered within the limits of that representing good practice in white iron compositions but which failed to respond to a 36-hr. anneal and which also failed to give good malleable by the use of the present industrial annealing period.

The examination of the chemical composition of this iron and its comparison with that of some other heats of white iron which had produced "picture frame" when annealed by the present

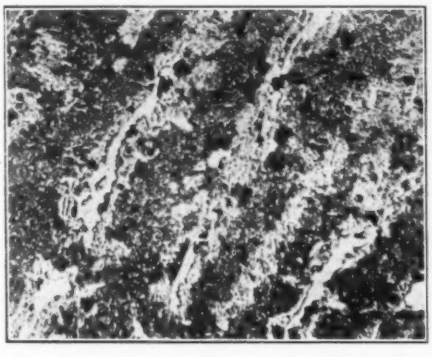

Fig. 2.—Normal Graphitising White Cast Iron, plus 0.02 per Cent. Sulphur, Melted and Cooled in Induction Furnace. × 100. The White Constituent is Free Iron Carbide.

commercial method revealed the fact that all of these irons were slightly high in sulphur (containing 0.06 to 0.08 per cent.) and somewhat low in manganese.

As far as experience with a number of samples of white iron can be relied upon it seems to be the case that slow graphitising white iron requires longer time for absorption of the free iron carbide at the high temperature. Slower rates of cooling are also necessary completely to break down all of the combined carbon in such samples.

Thus 4 or 5 hrs. at 927 deg. C. is sufficient time at the high temperature to absorb free iron carbide in samples which do respond to annealing cycles of from 20 to 30 hrs., while this sample which did not respond to such a treatment required more than 11 hrs. for this change to take place.

In short, the time necessary to absorb the free iron carbide at the high temperature seems to be a criterion as to whether or not the white iron will respond to a short annealing period.

This test should be useful in determining whether or not such a shortened anneal can be applied to any given heat of white iron, but something more important than this is suggested by the results which follow.

A sample of a white iron which did respond to a 26-hr. anneal and another sample of the same

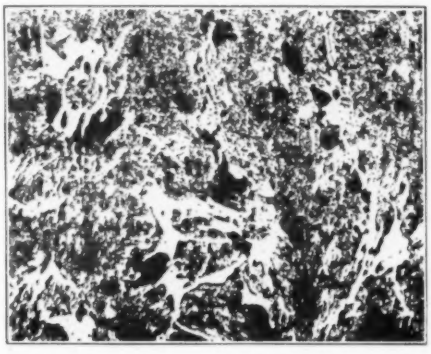

Fig. 3.—White Cast Iron Resistant to Graphitisation, Melted and Cooled in Induction Furnace. × 100. White Constituent is Free Iron Carbide.

iron to which 0.02 or a per cent. of sulphur had been added were melted in magnesite crucibles in an induction furnace and were allowed to cool with the furnace. Fig. 1 shows the resulting structure of the sample without sulphur added and Fig. 2 is that produced by addition of the sulphur.

Following this one sample of the white iron which did not respond to the short anneal and another to which 0.20 per cent. of manganese had

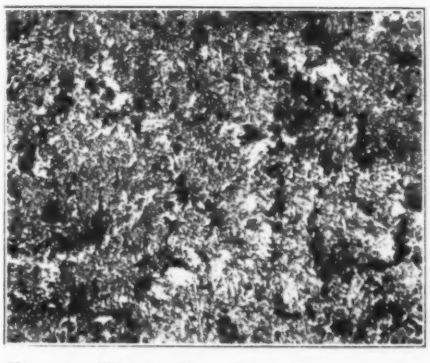

Fig. 4.—White Cast Iron Resistant to Graphitisation, plus 0.20 per cent. Manganese, Melted and Cooled in Induction Furnace. × 100.

been added were melted and allowed to cool in a similar manner. The structures produced are shown in Figs. 3 and 4 respectively.

These samples were then given a 30-hr. malleabilising anneal with the result that the samples of Figs. 1 and 4 malleabilised, while samples of Figs. 2 and 3 did not.

This indicates that sulphur has a very great influence upon the rates of graphitising of white cast irons and that the difficulty in this case can be completely corrected by the addition of a small amount of manganese.

* A Paper read before the Syracuse Meeting of the American Foundrymen's Association. The research was carried out at the Iowa State College.

Making Miscellaneous Steel Castings for Navy Use.

BY LT.-COMMANDER D. F. DUSEY,* Puget Sound, Wash.

Varied Work for the Navy Steel Foundry.

A navy yard steel foundry, unlike the average commercial steel foundry that selects a certain line of manufacture, cannot choose its work, but instead must accept what the fleet provides. The fleet provides a field so large and ever progressive that, except in the case of standard fittings, such as valves, flanges, etc., any extensive experimenting with the view of establishing a "best method" is out of the question. Each individual case becomes a problem that must be solved at the time.

On commercial vessels cast iron is used extensively. On combatant vessels, where weight is always at a premium and high pressures are the rule, steel is in general use. All main and auxiliary steam line valves and fittings must be of steel, as must all other units subjected to line steam, for the reason that superheated steam is in general use. Turbine casings are of steel, and the hull itself requires large steel castings, such as the stern and stem castings. The number of smaller steel castings, from one pound up, that may be required at any time runs into the

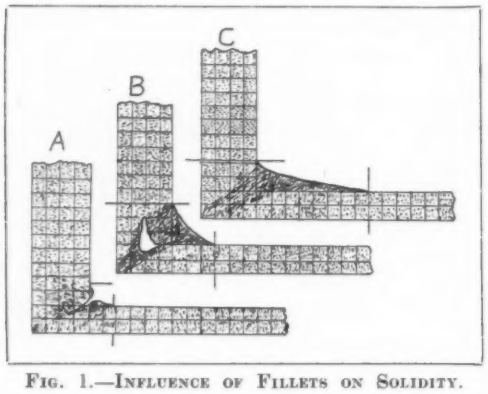

FIG. 1.—INFLUENCE OF FILLETS ON SOLIDITY.

thousands. While the weight of individual castings averages two hundred pounds, there is required, from time to time, castings that weigh as much as fifteen tons.

Space on board ship is limited, the hull shape, for obvious reasons, is fixed. In installing the various units in the vessels, it is found that where ordinarily it could be expected to use a simple shape, the configuration is such that an intricate shape must be used.

Demand for Castings Varies.

The demand for steel castings by the fleet is by no means constant. Where alterations are concerned, the requirements are known in advance. Under these conditions moulding, melting, etc., can be systematically carried out. Ordinarily, "jobbing" prevails. During one week there may be required six or seven tons of steel; then for the following month but one ton will be required. This latter amount may be required in one heat; or emergency conditions arise such that four or five separate heats will have to be run. As typical of the fluctuating load handled by the steel foundry the following data are quoted:—Good castings in high month, 220,000 lbs.; monthly average during past year, 27,840 lbs.; low month during past year, 2,423 lbs.; and total during past year, 143,674 lbs.

During the low month 121 pieces, average 20 lbs. each, were cast. During the high month 103 pieces, averaging 270 lbs. each, were cast. The largest single steel casting weighed 26,000 lbs., the smallest 2 ozs. To furnish such an assortment of castings and furnish them at a minimum cost under conditions as outlined above is the problem with which the foundry is confronted.

* An abstract from a Paper presented to the Syracuse meeting of the American Foundrymen's Association.

Equipment of Foundry.

There is one shop; this shop handles both the ferrous and non-ferrous metals. It is equipped with tracks, travelling cranes, fixed cranes, core oven, sand blast, flask repair facilities, mixing machines, flasks, ladles, testing and analysis apparatus, pits, etc., that are used in common for both ferrous and non-ferrous metals.

For steel there is a one-ton converter and a six-ton electric furnace. This latter furnace, though only rated at six tons capacity, easily handles ten tons, and on occasions, with the charging doors and pouring spout bunked, fourteen tons have been melted; by adding to this three blows from the converter, it has been possible to get a maximum single pouring consisting of the fourteen tons, plus three times the converter capacity.

Green Sand Facing Developed.

The shop was originally designed and built for an iron and brass foundry. During rush periods it was found that the core and mould drying ovens were not of sufficient capacity to handle the requirements for iron and non-ferrous metals, let alone attempting to dry the steel moulds. This led to the development, by the master moulder, of a green sand facing, consisting of the best grade of silica sand bonded with a minimum of high grade fire-clay. The sand and fire-clay were tempered with molasses water and a small amount of crude oil added. This facing, while limited in its application, was applicable to the extent of tiding over the rush periods.

Filleting Important.

Of the "rush" jobs encountered, high pressure steel valves and fittings form no small proportion. Improper filleting and uneven distribution of metal produces a valve that is like a case of hives to the operating engineer. Fillets that were considered satisfactory in the pattern shop produced cracks in the castings unless the moulder happened to be sufficiently experienced to cut heavy fillets in the mould. Such heavy fillets, used at random, while preventing surface cracks, often resulted in shrinkage profits.

In view of the import of obtaining a satisfactory, dependable valve at the first casting, a fillet, shown at C, Fig. 1, was developed. The fillets shown at A and B proved unsatisfactory. In casting the ordinary run of valves, both large and small, this fillet, C, has obviated the use of brackets or chills; the latter are only resorted to when there is a radical difference in the sections to be joined.

Position of Gates and Risers.

It was also found that the position of gates and risers played no small part in the elimination of cracks and distortion of the castings. A 7-in. high pressure steel angle valve, moulded similar to the 7-in. globe valves that had proved very satisfactory in the past, resulted in several rejections. By re-positioning the gates a satisfactory valve was obtained, and subsequently no further difficulty was experienced with this special type of valve. Other classes of castings that had a tendency to warp or deviate from their natural position were held in proper alignment by a judicious allocation of risers and gates.

The above devices are submitted as being illustrative of the methods employed in handling the divers problems that arise from time to time.

THE IRON AND STEEL INDUSTRY UNION in Czecho-Slovakia, to which belong the Prague Iron and Steel Company, the Wiskowitz concern, and the Rotava Nydeck and Hradek Works, have formed an independent company with a share capital of 1,000,000 Czech crowns (£6,315) for the sale of the Union's iron and steel products both at home and abroad.

AN ANGLO-SOUTH AMERICAN ASSOCIATION has been formed, with offices at 25, Haymarket, S.W.1, for the promotion of British trade in South America. This Association has only one object—to inform public opinion on the vital urgency of recapturing the Latin-American markets. It has the support and co-operation of some of the most prominent business men in the country. Among those who have already promised to be vice-presidents are Sir Godfrey Baring, Bart., Commander Sir Trevor Dawson, Bart., R.N., Sir Robert Hadfield, and the Hon. Sir Arthur Stanley.

Discussion on Mr. H. J. Young's Paper on "A Description of the Perlit Process."*

The President (Mr. M. B. Herbst), opening the discussion, expressed the opinion that the lecture had been a most instructive one.

Mr. W. J. Paulin said that in all Mr. Young's condemnation of the present condition of cast iron, as achieved in the foundry, he thought the fact had been overlooked that much had been done to eliminate many of the troubles which would be common in the ordinary casting if made without the precautions adopted at the present day. The Newcastle Branch had heard lectures on the use of chills, which overcame many of the troubles arising from porosity caused through heavy sections joining normally light ones.

The idea of getting combined carbon in so minute a form and regularly dispersed over all the casting was one which, of course, had been attempted fairly successfully by that well-known American, McLain. The process he advised and adopted was really the introduction of a certain amount of steel into the iron in such a way that the iron was vastly improved in its crystalline structure. There was no doubt that right through the casting the metal benefited by it, but it was pointed out that to mix ordinary pig-iron or cast iron with steel would not produce the same effect.

Mr. Young's Paper touched only lightly on the process itself, and was more a description of the results obtained. From what could be gathered, however, the mould had to be exceedingly hot.

The speaker had been thinking for some time that some of the objections which had been made against dry-sand moulding, because of the expense of drying the mould, would have been removed if advantage had been taken of the fact that with a dry-sand mould low-silicon iron could be used. This, one would not dare to have done with a green-sand mould, because, of course, of the chilling effect of the green sand, which would have brought about great stress, and very little additional stress in service would have caused the metal to rupture.

It appeared that this Perlit process, about which he (Mr. Paulin) knew but little, was really an extension of the dry-sand mould question, having gone further.

The process had deliberately made use of low-silicon iron, and, by so doing, had brought about naturally the closing of the structure of the metal.

He would like to have heard from Mr. Young something of the difficulties in handling the process. It was obvious that there would be some difficulty in handling moulds which were heated to such high temperatures. He understood that it was possible to heat the moulds as they stood, that is, without taking them into the stove, but this, of course, required special apparatus.

The present-day foundryman must admit that, whatever he might have thought of the iron he had been able to get hitherto, its possibilities for use in the future are going to be vastly restricted. The foundry of to-day, in spite of running costs, had to take what it could get for its castings.

It would appear that, with the requirements which have been shown by experience of castings for the Diesel engine, Perlit iron has become almost a necessity. Take, as an example of progress, the case of the motor car. One is forced to realise that, without all that had been devised in the way of heat-treatment of steel, etc., the motor car of the present day would never have existed. Similarly one looks for great possibilities in Perlit iron.

Perlit and the Use of Chills.

In reply, the Lecturer said that Mr. Paulin had appreciated some of the best points in the process.

Chills were a device of the foundryman to improve certain defects, and they could still be used in the Perlit process for certain castings. At the present moment there is a patent coming out for the application of the Perlit process to propellers. As it was necessary to heat up the tip of the blade, so was it necessary to chill the root. Consequently chills would be as valuable in the future as they are at present. Semi-steel would be just as popular as ever, because some forms of Perlit could be made from a semi-steel mixture if desired.

Mr. Paulin was correct in what he said regarding green-sand moulds and dry-sand moulds.

That week he (the lecturer) had been in one foundry where to instal the Perlit process would probably cost about £1,000, and he had been in another foundry where it would cost them very little. It depended upon the particular foundry and whether it had suitable core stoves as to how much it would cost to introduce the process. Disadvantages of every new thing were bound to exist. The disadvantages of making chills and inserting them were great, but they were used, nevertheless. There was nothing without its difficulties, but this fact was not to be allowed to obstruct progress. One thing necessary for the satisfactory working of the process was foundry organisation—it required a good foreman or foundry manager to arrange the work.

With reference to those foundries which complain that they have no work, he said that Perlit orders were going abroad. The reason why ordinary cast iron could not command a good price was because it was "any old thing," instead of being something reliable. It was necessary to keep up with modern developments and to produce something which was not the cheapest in quality.

He personally thought that Perlit iron would get higher prices. The extra cost of heating the moulds to, say, 300 to 400 deg. C. was not so prohibitive, and many foundries had core stoves already that would do it.

The Case of a Propeller.

Mr. James Smith, referring to the photograph of the ordinary cast-iron propeller blade shown on the screen, pointed out that the lecturer had told them that the tip of the blade was bad metal, towards the centre of the blade the metal was better, whilst at the root is was porous. If that propeller was cast with Perlit, would it be the same quality throughout? Also, supposing a bar 4-in. thick by 2-ft. long was cast in Perlit iron and afterwards broken in two, would the grain of the iron be the same in the centre as on the outside?

The Lecturer, in reply to Mr. Smith, said that he had put the photograph of the propeller casting on the screen because he knew that in so doing he was choosing one of the most extreme cases with which the foundryman had to deal. It was one of the most difficult castings to make, and also one giving the best example of the thing he wished to speak about, namely, the influence of cooling.

The great trouble with a propeller was at the edges. If the mould at those places was heated to suit the iron used, then the propeller would be a great deal better at the edges. The root would be as bad as at present, because that part would need chilling.

Mr. Smith had mentioned a case, however, which was not so extreme as the propeller, namely, that of a bar 4-in. thick by 2-ft. long. The lecturer here recalled a lantern slide showing four Diesel Perlit fuel valves, 5¼-in. dia. in centre, saying that in his Glasgow Paper he had stated that the valves were very superior to the same type of casting made in ordinary iron, and he also showed sections of the iron illustrating that the Perlit was homogeneous whilst the one in ordinary iron was not.

Railway Chairs.

Mr. R. O. Patterson remarked that it appeared to him that the Paper was a description of the existing processes of making castings, and he did not think that they had learned very much about Perlit. In the course of his lecture Mr. Young mentioned railway chairs, and when railway chairs were mentioned he (Mr. Patterson) was interested. He did not know what the cost would be if moulds for these chairs had to be heated and poured with Perlit iron. They cost now about 6s. or 7s. per ton to make in the ordinary way. Failure through breakages was cer-

* This Paper was printed in our last issue.

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tainly not more than 10 per cent., the majority failing by reason of abrasion.

From what he had seen of the practice of Perlit iron, however, it was an object after which they should all strive. He noticed that Mr. Young stated in his Paper that it was possible to use different temperatures of moulds providing that different qualities of iron were used to suit these temperatures. He believed that in America they were obtaining good results by merely paying more attention to their cupola mixings.

Mr. Young, recalling Mr. Patterson's remark about the Perlit process coming from Germany, said that, firstly, if everything was wiped out which came from abroad the world would be in a sad state. Secondly, science knew no nationality and could not shut its eyes to knowledge gained anywhere. Also, he could not help thinking that if the last speaker got a good order at a good price for Perlit iron, he would not object to it. Perlit was suitable to resist wear, abrasion and impact. In some trades Perlit might be slightly more expensive than their ordinary iron, but it was better than ordinary iron and would fetch a better price.

Mr. A. Logan said he came hoping to hear a description of the Perlit process, but he thought Mr. Young had described the application of the Perlit process rather than the process itself. Speaking as a metallurgist, however, he was convinced that this process had an assured future. At the present moment most of the foundries in the country were focussing their attention upon this matter, and most metallurgists were convinced that it was the process of the future. He wondered how a foundry which had no scientific control would make this metal, as of course, it was necessary to have controlled composition. He personally did not think there was any great difficulty with regard to the actual mould temperatures, because, of course, the moulds could be closed before heating. In conclusion, he said he felt sure that sooner or later every foundry in this country would have to turn out high grade cast iron.

Mr. Young, in reply, said that in the Paper which he had read at the recent Glasgow Convention he had stated that a foundry without a laboratory could not work the Perlit process. Mr. Logan was well aware that it did not matter, Perlit process or any other process, it was impossible to control the composition of iron without a laboratory. Some of the speakers seemed to think that he could have described the process more fully than he had done, but he failed to see what further description could have been given. Mr. Logan knew perfectly well what was done, as did any other chemist.

Mr. H. F. Parsons: At what temperature must the mould be?

Mr. Young: That depends upon the composition of the metal and the thickness and mass of the casting.

Mr. Edward Smith: Can you give an average temperature?

Mr. Young: 300 to 400 deg. C.

Mr. Paulin: Would it be possible, without special heating apparatus, such as a portable furnace, to get the moulds in position heated to a sufficiently high temperature for the Perlit process?

Heating Methods Used.

Mr. Young replied that there was a special apparatus obtainable for heating or drying floor moulds, which used about 32 lbs. of coke per hour. This apparatus was used at many foundries in this country.

Mr. Logan asked if, when a large mould was dried in the floor, trouble was experienced through the mould getting too hot in places.

Mr. Young replied that the practical difficulty of drying the mould at the same temperature all over was quite overcome by baffling the flame.

Mr. J. Bell said he had been very interested in Mr. Young's Paper, and thought it was a pity there was not more time left for controversy. He himself had been making some experiments lately. Out of the same ladle he cast three bars in moulds of varying temperatures, the bars being of 1-in., 2-in., and 3-in. section respectively, and they varied in tensile strength only from 22 tons to 22.8 tons.

The lecturer had stated that one of the ways of working the Perlit process was to keep the mould temperature constant and vary the composition of the metal to suit that temperature, but it seemed to him (the speaker) that, no matter what composition of metal was used, it would still be influenced by rate of cooling.

The Lecturer congratulated Mr. Bell upon having done some experiments and having had such good results. It proved, he thought, what a young worker could do if he followed up modern knowledge.

Mr. Bell had not quite understood what he meant, however, when he said that one could vary the metal and keep the mould temperature constant or *vice versa*. What he meant was this: If several moulds were being poured in a line, the castings varying in thickness, the thin ones could be cast first and the thick ones last, and that was what was meant by varying temperatures. On the other hand, in a foundry where there were several cupolas, it would be possible to get the same effect by pouring the castings with different metal, the moulds all being at the same temperature.

Mr. Bell: If a casting has unequal sections, is there not unequal cooling?

Mr. Young replied that most castings have different sections. The globe valves shown on the screen had several different sections, but if Mr. Bell will make some of those castings, precisely as he has cast his test bars, he will find that the globe valves had equal grain size in all sections.

Mr. James Smith proposed a hearty vote of thanks to the lecturer, and said that he thought the Paper had been most instructive.

Mr. R. O. Patterson, seconding, remarked that they were all out for the improvement of iron castings.

The Beta Transformations in Copper-Zinc Alloys.*

By J. L. Haughton, D.Sc. (Teddington), and W. T. Griffiths, M.Sc., F.I.C. (Woolwich).

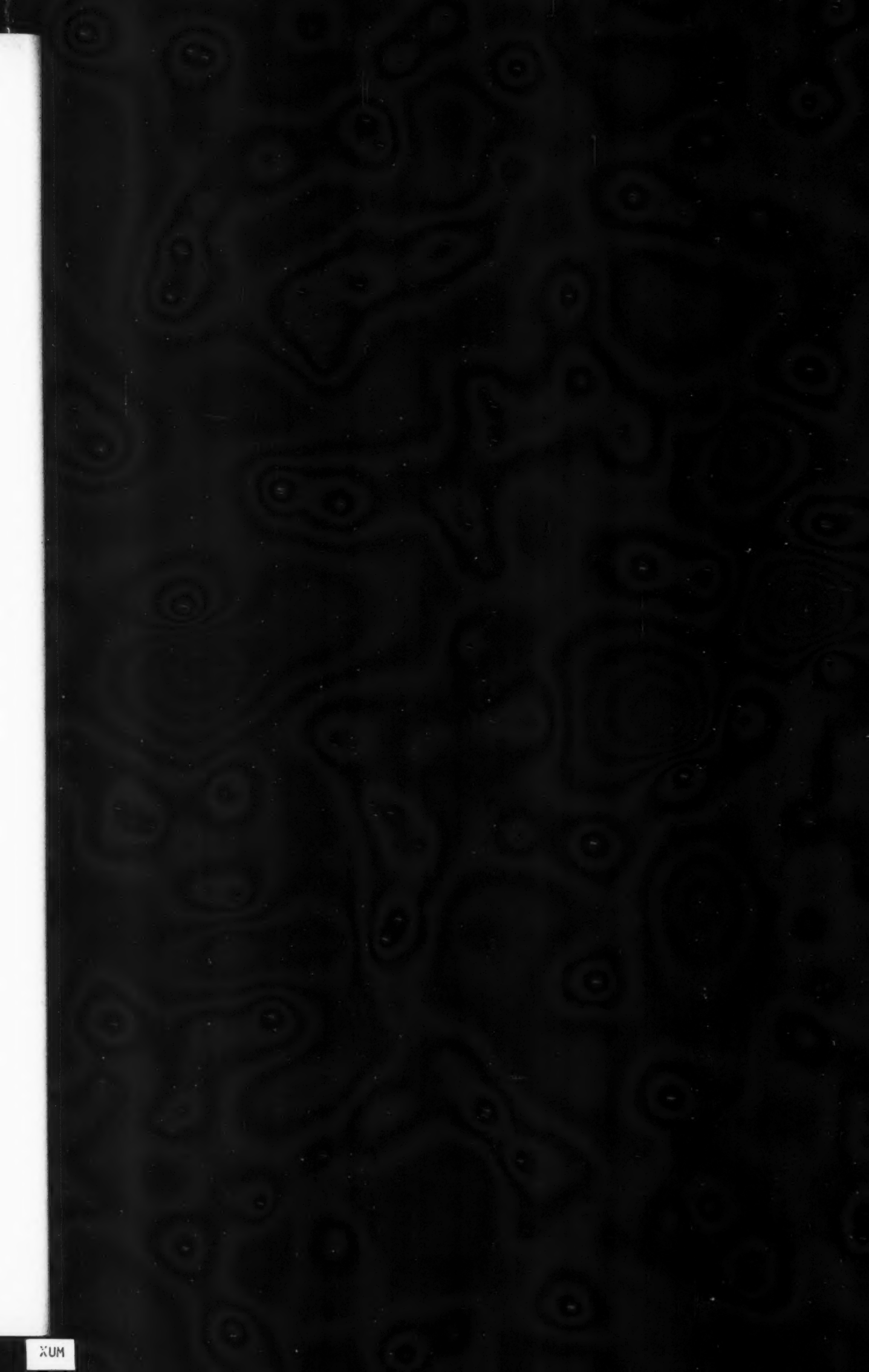
[Summary.]

With a view to determining more exactly the temperatures of the transformations which take place at about 460 deg. C. in the β constituent of copper-zinc alloys, the change of resistivity with temperature was determined for a number of alloys containing from 46 to 63 per cent. copper. Rates of heating and cooling varying from the order of 2 deg. per hour upwards were employed, the apparatus used being that described by the authors in the "Journal of Scientific Instruments," 1924, 1, p. 225. The results show that (*a*) above 55 per cent. copper the transformation temperature is 453 deg. C.; (*b*) between 55 per cent. and 51 per cent. copper it takes place at temperatures rising from 453 to 470 deg. C.; and (*c*) with less than 51 per cent. copper the transformation temperature is 470 deg. C. These data are opposed to the theory that this is a eutectoid transformation.

The specific resistances of these alloys at room temperatures were also measured after carefully annealing just above the transformation point and slowing cooling over a period of two days. The method adopted was that of comparing the potential drop between two points of known distance apart on the specimen with that across a standard resistance while a steady current was passed through both. The results show that the resistance falls rapidly as the copper decreases from 61 per cent. to 53.5 per cent.; it then falls less rapidly to about the 50 per cent. copper alloy and rises steeply from this point with further decrease of copper content. The resistance-composition curve thus marks clearly the two boundaries of the field at room temperature as occurring at 50.0 and 53.5 per cent. of copper.

A portion of the constitutional diagram of the copper-zinc alloys embodying the results obtained is reproduced.

* A Paper read before the Institute of Metals.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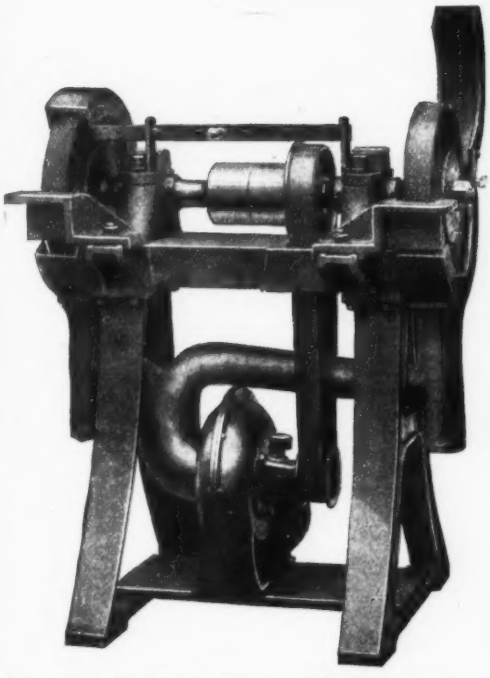

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Trade Talk.

Cox & Danks, Limited, have raised the G103, the first of the larger German destroyers sunk in Scapa Flow.

Considerable damage was caused by fire to premises belonging to the Blake Boiler Company, Albert Hill, Darlington.

The Hodbarrow Iron Ore Mines at Millom, Cumberland, are closing down again owing to the condition of trade.

A. & J. Inglis, Limited, of Pointhouse, Glasgow, have an order for a Diesel-engined train ferry for service in South America.

Rubery, Owen & Company, constructional engineers, Darlaston, have opened offices at Norwich Union Chambers, Congreve Street, Birmingham.

The General Brass Fittings Company, Limited, are being wound up voluntarily, with Mr. E. Cooper, of 49, Eastcheap, London, E.C.3, as liquidator.

Dowding & Dickinson, Windsor House, Victoria Street, London, S.W.1, have been appointed sole British agents for the Pfauter gear hobbers, worm millers, and hob and cutter grinders previously in the hands of Schuchardt & Schütte.

A contract has been awarded by the County Council of the West Riding of Yorkshire to the Cleveland Bridge and Engineering Company, Limited, of Darlington, for the construction of a new bridge over the River Ouse at Boothferry, near Goole.

Gregson & Partners, Limited, gas, constructional and furnace engineers, Wharncliffe House, Bank Street, Sheffield, have appointed Mr. H. Pearse, of 12, Lorne Terrace, Darlington, as their representative for the North of England and Scotland.

James Turnbull & Company, electrical and mechanical engineers, 3, New Street, Birmingham, have been appointed Birmingham and Midlands representatives for E. G. Appleby & Company, Limited, 70, Victoria Street, S.W.1, for the sale of their gas producers, lifting magnets, etc.

Harvey-Siemens Furnaces, Limited, have removed from 70, Victoria Street, to 26, Victoria Street, Westminster, S.W.1, The company have just received an order from the Sté Ame Usines Métallurgiques du Hainaut for a continuous pusher furnace to heat 25 tons of steel blooms per hour, using blast-furnace gas

Guest, Keen & Nettlefolds, Limited, have secured an American order for 20,000 tons of hematite. This will be manufactured at the Dowlais Works, Cardiff, and is to be delivered in the United States over the next three months in cargoes of about 3,000 tons. The contract, it is understood, has been accepted at a low price in order to keep the furnaces in blast.

The Australian Commonwealth Engineering Standards Association, Macleay House, 16, College Street, Sydney, is establishing a collection of trade catalogues and similar commercial material in connection with the Association's library, which, with the very extensive library of the Institution of Engineers, Australia, is available for the use of members of both organisations. The Association is desirous of being placed on the mailing list of engineering and allied firms for the receipt of their publications.

Edgar Allen & Company, Limited, Imperial Steel Works, Sheffield, announce that their tramway department has just completed a very large layout for Auckland, New Zealand, consisting of a double track three-way junction, both tracks being carried through. The total weight of manganese steel used in this is 70 tons. This department has also in hand several layouts for Manchester, Liverpool, Belfast, and foreign countries. The forging press department has produced a considerable quantity of special quality blooms for forgings connected with dredger plant. The saw department is rather slack, but an interesting contract has been received from Spain for cold saws and friction discs.

A reply to the Ilford Council, who recently placed contracts for fourteen miles of electric cable with a German firm, declaring that their object is to break a "ring" of English cable manufacturers, has been made by an official of Callender's Cable & Construction Company, Limited. "As to the existence of a 'ring,'" he said, "it all depends on what is meant by a 'ring.' There has been in existence for many years the Cable Makers' Association, the main object of which is to maintain the high standard of British cables. The electrical cable industry was investigated by a sub-committee of the Standing Committee on Trusts, and the report of the Committee, which was presented to Parliament in 1921, contained the following :—The policy of the association generally has been to secure standardisation. A further object has been to regulate wages and working conditions. It has been definitely stated to us that the association as such does not deal with selling prices. Standard prices of cables of specified qualities and grades are, however, agreed upon by the members and standard price lists are issued from time to time."

Personal.

Sir Edwin Grant-Burls has relinquished his position as a director of the Bengal Iron Company, Limited. Mr. J. Angus, Mr. G. H. Fairhurst, and Mr. H. FitzPatrick have been elected directors of the company.

Captain C. Stephenson has been the recipient of a presentation from the officials at Swan, Hunter & Wigham Richardson's shipyard, Wallsend, on the occasion of his leaving to take up an appointment with Catherall & Company, of Hexham. Captain Stephenson, who is a son of the late Mr. C. Stephenson, manager of the Wallsend shipyard, served his apprenticeship with Swan, Hunter & Wigham Richardson, Limited.

Mr. C. E. Gausden has been appointed general manager of steel sales to the British Empire Steel Corporation, in which capacity he has been acting since the death of Mr. E. P. Merrill. Mr. Gausden is a native of London, and has been connected with the coal and metal trades for more than twenty years. After the South African war he went to Rangoon as sales agent for a coal company, and in 1906 went to Canada in the service of Drummond, McCall & Company. In 1911 he became managing director in Canada for Heap & Partners, and in 1913 was appointed agent for A. G. Kidston & Company, of Glasgow, with offices in Montreal and New York. Mr. Gausden joined the staff of the British Empire Steel Corporation in 1922 as manager of the export department.

Wills.

Carmichael, G. H., engineer, Broughty Ferry	£22,946
Hattersley, C., late of Hattersley Bros., Queen's Foundry, Swinton	£46,762

Contracts Open.

Barking, October 21.—Bridge, etc., for the Minister of Transport. The Chief Engineer, Roads Department, Ministry of Transport, 7, Whitehall Gardens, S.W.1. (Fee £25, returnable.)

Bristol, October 19.—Electric capstans, etc., for the Docks Committee. Mr. T. A. Peace, chief engineer, Avonmouth Dock, Bristol. (Fee £3, returnable.)

Cairo, December 1.—Pumping units, etc., for the Ministry of Public Works, Cairo. The Department of Overseas Trade, 35, Old Queen Street, London, S.W.1. (Reference A.X. 2429.)

Dublin, October 27.—Sludge elevators, for the Commissioners. The City Treasurer, Exchange Buildings, Lord Edward Street, Dublin, or from Mr. J. S. Alford, 11, Victoria Street, Westminster, London, S.W.1. (Fee £1 1s., returnable.)

Horsham, October 20.—Water mains, for the Horsham U.D.C. Mr. C. G. Atkinson, surveyor and water engineer, 3, Market Square, Horsham.

London, S.E., October 19.—Cranes, for the Director-General, India Store Department, Branch No. 14, Belvedere Road, Lambeth, London, S.E.1. Tender forms obtainable from above.

London, S.E., October 20.—Locomotives, for Barsi Light Railways Company, Limited, 307, Winchester House, Old Broad Street, London, E.C.2. (Fee 20s., non-returnable.)

London, S.W., October 20.—Girder bridges, for the Madras and Southern Mahratta Railway Company, Limited, 25, Buckingham Palace Road, London, S.W.1. (Fee £1 1s., non-returnable.)

Newport, Mon., October 28.—Pumping plant, for the Corporation of Newport. Mr. A. N. Moore, borough electrical and tramways engineer, Town Hall, Newport, Mon. (Fee £3 3s., returnable.)

Obituary.

Mr. G. D. Weir, a well-known engineer, died at his home at Sunderland, on October 4, aged 55. In 1902 he was general manager at the North-Eastern Marine Engineering Works, at Sunderland. He was a member of the council of the North-East Institute of Engineers and Shipbuilders, and a member of the Institute of Naval Architects.

Captain M. H. P. Riall Sankey died suddenly on October 3 at his residence, Hurley, Castlebar Road, Ealing. The deceased gentleman, who was in his 72nd year, was a past-president of the Institute of Mechanical Engineers, and a vice-president of the Institution of Civil Engineers. He was director and consulting engineer of Marconi's Wireless Telegraph Company, Limited. After retiring from the Royal Engineers, which he joined in 1873, he was associated with the board of Willans & Robinson, Limited.

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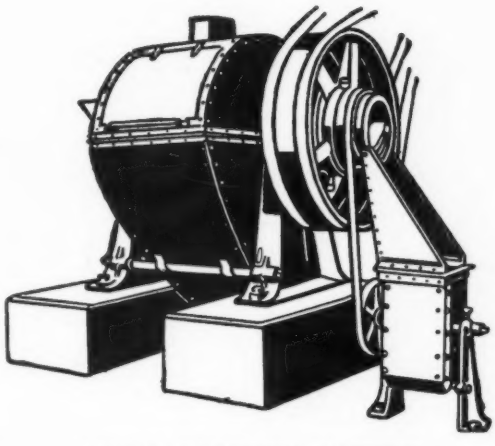

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IRON AND STEEL MARKETS.

Pig-iron.

MIDDLESBROUGH. — Anticipations of a long-delayed improvement in the Cleveland iron trade appear to be on the point of materialising, but while there has been of late a somewhat better volume of inquiries, it is still difficult to persuade some buyers that bed-rock prices have yet been reached. At the same time trading is not restricted to the meagre proportions for a long time the rule in this market. These conditions, due in measure to recent slackness in the foundry industry at home, and the absence of substantial export business, have naturally had a restraining influence on furnace outputs, with the result that the unexpected increase of demand will probably have a hardening effect upon prices, a contingency by no means improbable in the near future. The position of the export trade at the moment will be more readily explained by the following details:—The shipments of pig-iron from Middlesbrough during September amounted to 26,479 tons, as against 28,496 tons in August, a decrease of 2,017 tons. The coastwise trade accounted for 11,902 tons, of which Scotland took 10,222 tons. Prices, meanwhile, are unchanged, and at this week's markets registered greater steadiness, No. 3 G.M.B. being offered at 66s. 6d. per ton, while the premium on the No. 1 foundry was down to 3s., making the price 69s. 6d. per ton, No. 4 foundry was quoted at 65s. 6d., and No. 4 forge at 65s. per ton.

In the Tees-side hematite market the outlook being distinctly healthier than that for foundry, though this is not saying a great deal, for the volume of business passing is still very much below normal. However, there is more business moving, and one firm which had recently contemplated closing down is now fully sold over this month, and is well booked into November. The quotation for East Coast mixed numbers is firmer at 74s. 6d. per ton, with the No. 1 quality 75s. per ton. On the North-West Coast quotations for Bessemer mixed numbers now stand at £4 2s. 6d., c.i.f. Welsh ports; £4 4s. per ton, delivered at Glasgow; £4 7s. per ton, delivered at Sheffield; and £4 12s. 6d. per ton, delivered at Birmingham.

LANCASHIRE.—The demand for foundry pig in this area continues on a restricted scale, and business in the local markets is again confined to almost retail volume. It is reported that the selling agents for the Derbyshire furnaces are still quoting 73s. 6d. delivered in Manchester for No. 3 foundry iron, and do not admit that this price has been broken by more than 3d. per ton. Very few Derbyshire sellers now try for 75s. in Manchester, although, perhaps, one or two brands are charged at that price. The demand for Scotch iron is only small, with a tendency to ease in prices; probably 96s. to 96s. 6d. would now be accepted for delivery in Manchester.

THE MIDLANDS.—Business in this district is again reported inactive, and the majority of consumers are still content to carry on in this manner rather than book ahead. Of course this state of affairs always obtains in a falling market. Ruling prices are as follow:—Derbyshire No. 3 foundry, 65s. to 67s. 6d.; Staffordshire No. 3 foundry, 67s. 6d.; Northants No. 3 foundry, 61s. to 62s. 6d.

SCOTLAND.—There has been no improvement in the demand for Scotch iron, and the price of No. 3 has eased to 79s. at the furnaces. At this price Scotch iron appears to be too dear or Cleveland is too cheap, but the makers of both complain that the respective prices are not remunerative. The recent improvement in the export demand has not been maintained this week, and only some small lots have been sold abroad.

Finished Iron.

Reference has already been made to last week's reduction in crown and common bars. There is good reason to believe that the amount given out (7s. 6d.) is more or less a paper figure, and that what has really happened is the withdrawal of all price control. Experience will soon afford confirmation or otherwise. The real difficulty in the way, however, is not so much price as paucity of demand. Under this heading still further reductions are shown in the official return recently issued, as compared with both the previous two months at the corresponding period of 1924, the latter being rather a substantial decline. If, however, demand were sufficient to afford full and constant employment manufacturers would not be so very badly off even under present price conditions. Apart from marked and special irons, demand is very inadequate, and recently in gas strip it has not been sufficient to occupy fully even the limited plant now in operation.

Steel.

The tone of the steel trade was not any better. Manufacturers in the South Staffordshire district are being greatly upset by the fierce competition of those in other parts of the country, who, in their search for tonnage, are cutting up the Midland trade very badly. The recent low prices for angles and plates have mostly come from North Country makers, who make £7 10s. delivered for angles look a very lean price. The same remark applies to plates at £8 12s. 6d., or perhaps a shade less, and, of course, it is the explanation of boiler plates at £11 15s. Black Country makers, with a smaller market to draw on, are badly hit by these incursions. Conditions are far from good in small bars and the commoner kinds of hoops and strip. The larger makers are cutting, and it is doubtful if small bars, for instance, would fetch more than £8. Fortunately the galvanised sheet trade maintains its strength; that is the one satisfactory branch of the trade.

Scrap.

Inquiries for foundry scrap in the various markets for this class of material continue on a minimum volume, and in most cases a further weakening of values is noted. In the Midlands, however, cast-iron scrap is still firm at 77s. 6d. to 80s. per ton, but the demand is not so good as has been the case for some time past. The majority of the foundries appear to be fairly well stocked, and are of the opinion that in view of the present prices of pig-iron this figure should be reduced. In Scotland, machinery cast-iron scrap has been recently sold at 72s. 6d. per ton. Old cast-iron railway chairs are not so plentiful now, but the price has not improved much. Some odd lots can be had at 71s. 3d. to 72s. 6d. per ton. Ordinary cast-iron scrap in pieces not exceeding 1 cwt. is still easy at 65s. to 66s. per ton, and for steelworks cast-iron scrap in furnace sizes 2s. 6d. per ton less. Light cast iron and firebars remain unchanged at 55s. per ton, but there are very small quantities being disposed of.

Metals.

Copper.—The steady tendency of values of standard copper continues unchanged, with quotations fairly well maintained at levels between £61 to £62 per ton. Whether this better feeling will be maintained is rather difficult to forecast at present; the most notable point about it is that it was not inspired by America. The statistical position of copper, of course, remains very sound, but values will not display true strength until consumers come into the market again as effective buyers. Current quotations:—*Cash*: Thursday, £61 5s.; Friday, £62 2s. 6d.; Monday, £62 7s. 6d.; Tuesday, £62 10s.; Wednesday, £62 7s. 6d.

Three Months: Thursday, £62 2s. 6d.; Friday, £63; Monday, £63 5s.; Tuesday, £63 7s. 6d.; Wednesday, £63 7s. 6d.

Tin.—The favourable statistical position of this metal is fully reflected in the recent market movements, with values advanced substantially, due to increasing strength of consumptive demand. There has, however, been some fear lest the position of near tin becomes rather seriously tightened for awhile, as it is quite on the cards that in the near future additional calls may be made on the available supplies in order to meet near consumers' needs on home and continental account. Current quotations:—*Cash*: Thursday, £271; Friday, £274 2s. 6d.; Monday, £274 17s. 6d.; Tuesday, £277 5s.; Wednesday, £279.

Three Months: Thursday, £272; Friday, £275 2s. 6d.; Monday, £275 17s. 6d.; Tuesday, £277 15s.; Wednesday, £279 10s.

Spelter.—In the market for this metal consumptive demand has been a shade more active of late, while producers are holding firmly, and disinclined to accept forward business except at advanced rates. Second-hand parcels from the Continent have again been offered with a little more freedom, but not in sufficient quantities to influence prices. Reports from the U.S.A. show little or no change in the market there, which remains consistently firm, the price still ruling above London parity. Current quotations:—*Ordinary*: Thursday, £39 2s. 6d.; Friday, £39 10s.; Monday, £39 17s. 6d.; Tuesday, £40; Wednesday, £40 8s. 9d.

Lead.—Movements in soft foreign pig have again indicated growing strength in values, due to increased demand and short supplies. Consumers at home are now experiencing difficulty in placing orders for early delivery, while requirements in other parts of the world are also on a much enhanced scale, particularly in the United States. Current quotations:—*Soft foreign (prompt)*: Thursday, £39 7s. 6d.; Friday, £39 15s.; Monday, £39 17s. 6d.; Tuesday, £39 5s.; Wednesday, £39 2s. 6d.

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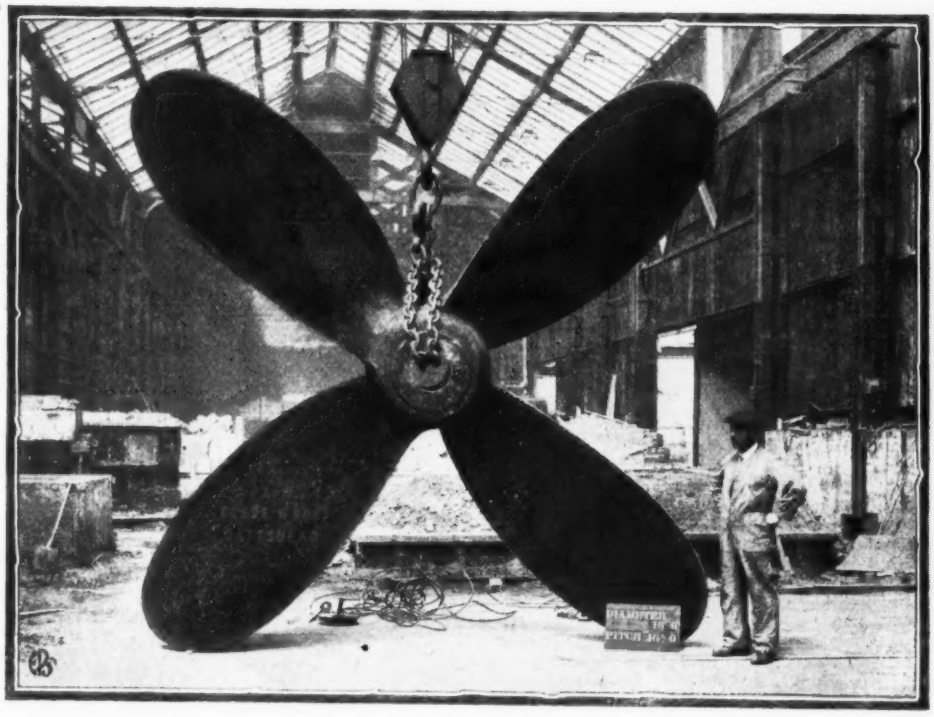

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We invite your enquiries for pig or castings. Brochure No. 304 gives full particulars of the analysis, the physical properties and the class of work for which each iron is suitable, and will be forwarded on request.

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WEEKLY PRICE CURRENT.

COPPER.

	£	s.	d.
Standard cash	62	7	6
Three months	63	7	6
Electrolytic	68	0	0
Tough	64	5	0
Best selected	64	15	0
Sheets	92	0	0
India	78	10	0
Wire bars	68	7	6
Do. Oct.	68	0	0
Do. Oct.–Nov.	68	2	6
Ingot bars	68	0	0
H.C. wire rods	72	10	0
Off. av. cash, Sept.	61	18	11 5/11
Do., 3 mths. Sept.	62	18	2 2/11
Do., Sttlmnt, Sept.	61	18	0 9/11
Do., Electro, Sept.	67	18	2 2/11
Do., B.S., Sept.	65	14	2
Aver. spot price copper, Sept.	61	18	0¾
Do., wire bars, Sept.	68	2	6
Solid drawn tubes			13½d.
Brazed tubes			13½d.
Wire			10d.

BRASS.

Solid drawn tubes	12d.
Brazed tubes	13½d.
Rods, drawn	11½d.
Rods, extd. or rlld.	7½d.
Sheets to 10 w.g	10½d.
Wire	10½d.
Rolled metal	9⅞d.
Yellow metal rods	7½d.
Do. 4 × 4 Squares	8d.
Do. 4 × 3 Sheets	8½d.

TIN.

	£	s.	d.
Standard cash	279	0	0
Three months	279	10	0
English	279	0	0
Bars	279	5	0
Straits	285	5	0
Australian	280	15	0
Eastern	284	5	0
Banca	284	5	0
Off. aver. cash, Sept.	259	3	8 7/22
Do., 3 mths., Sept.	261	0	0
Do., Sttlmt. Sept.	259	3	7 7/11
Aver. spot., Sept.	259	3	7½

SPELTER.

	£	s.	d.
Ordinary	40	8	9
Remelted	38	0	0
Hard	32	0	0
Electro 99.9	43	10	0
English	40	12	6
India	33	0	0
Zinc dust	45	0	0
Zinc ashes	15	0	0
Off. aver., Sept.	37	1	6 9/22
Aver., spot, Sept.	37	8	8¼

LEAD.

	£	s.	d.
Soft foreign ppt.	39	2	6
English	40	5	0
Off. average, Sept.	37	12	10 17/22
Average spot, Sept.	38	17	8

ZINC SHEETS, &c.

	£	s.	d.
Zinc sheets, English	45	0	0
Do. V.M. ex whf.	44	0	0
Rods	51	0	0
Boiler plates	43	10	0
Battery plates	44	0	0

ANTIMONY.

	£	s.	d.
Special brands, Eng.	74	10	0
Chinese	66	10	0
Crude	62	0	0

QUICKSILVER.

	£	s.	d.
Quicksilver	13	5	0

FERRO-ALLOYS AND STEEL-MAKING METALS.

	£	s.	d.
Ferro silicon 45/50%	12	7	6
Ferro silicon 75%	21	0	0
Ferro-vanadium—35/40%	16/– lb. va.		
Ferro-molybdenum—70/75% c. free	6/3 lb.		
Ferro-titanium—23/25% carbonless	1/1 lb.		
Ferro-phosphorus, 20/25%,	£22	0	0
Ferro-tungsten—80/85%, c.fr.	1/8 to 1/8½ lb.		
Tungsten metal powder—98/99%	1/11 to 1/11½ lb.		
Ferro-chrome—4/6% car.	£23	10	0
Ferro-chrome—6/8% car.	£23	0	0
Ferro-chrome—8/10% car.	£22	10	0
Ferro-chrome—Max. 2% car.	£40	0	0
Ferro-chrome—Max. 1% car.	£51	0	0
Ferro-chrome—Max. 0.70% car.	£56	10	0
Ferro-chrome—70%, carbonless	1/5 lb.		
Nickel—99%, cubes or pellets	£170 to £175		
Cobalt metal—98/99%	10/– lb.		
Aluminium 98/99%	£120		
Metallic Chromium—96/98%	3/9 lb.		
Ferro-manganese (net)—76/80%, loose	£15	7	6
Ferro-manganese (net)—76/80%, packed	£16	7	6
Ferro-manganese (net)—76/80%, export	£15	5	0
Metallic manganese—94/96%, carbonless	2/– lb.		

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL.

	s.	d.
Finished bars, 14% tungsten	2	6
Finished bars, 18% tungsten	3	6

Per lb. net, d/d buyers' works.

Extras—

Rounds and squares 3 in. and over	4d. lb.
Rounds and squares under ½ in. to ¼ in.	3d. lb.
Do. under ¼ in. to 1/16 in.	1/– lb.
Flats, ½ in. × ½ in. to under 1 in. × ⅜ in.	3d. lb.
Do. under ½ in. × ½ in.	1/– lb
Bevels of approved sizes and sections	6d. lb.
Bars cut to length	10% extra

Scrap from high-speed tool steel—

Scrap pieces	3d.
Turningds and warf	1d.

Per lb. net, d/s steel makers' work

SCRAP.

	£	s.	d.	£	s.	d.
South Wales—Hvy. steel	3	7	6 to 3	10	0	
Bundled steel & shrngs.	3	2	6 to 3	6	6	
Mixed iron & steel	3	2	6 to 3	5	0	
Heavy cast iron			3	7	6	
Good machinery for foundries			3	10	0	
Cleveland—Heavy steel			3	0	0	
Steel turnings			1	17	6	
Cast iron borings			1	15	0	
Heavy forge			3	17	6	
Bushelled scrap			3	0	0	
Cast-iron scrap			3	2	6	
Lancashire—Cast-iron scrap	3	10	0 to 3	12	6	
Heavy wrought	3	5	0 to 3	7	6	
Steel turnings			2	3	0	

London — Merchants' buying prices delivered yard.

	£	s.	d.
Copper (clean)	52	0	0
Brass (clean)	39	10	0
Lead (less usual draft)	35	0	0
Tea lead	31	0	0
Zinc	26	0	0
New aluminium cuttings	92	0	0
Braziery copper	47	0	0
Gunmetal	47	0	0
Hollow pewter	185	0	0
Shaped black pewter	134	0	0

PIG-IRON.

(f.o.t. unless otherwise stated).

N.E. Coast—Foundry No. 1	69/6
Foundry No. 3	66/6
Foundry No. 4	65/6
Forge No. 4	65/–
Hematite No. 1	75/–
Hematite M/Nos.	74/6
N.W. Coast—Hem. M/Nos. d/d Glas.	84/–
d/d Birm.	92/6
Midlands—Staffs. common*	—
No. 4 forge	62/6
No. 3 foundry	67/6
Shrops. basic	70/–
Cold blast, ord.*	185/–
roll iron*	190/–

* d/d Birmingham.

Northants forge	56/6
fdry No. 3	61/9
Derbyshire forge	57/6
fdry. No. 3	66/3
basic	67/6
Scotland—Foundry No. 1	84/–
No. 3	79/–
Hem. M/Nos.	79/–
Sheffield (d/d district)—Derby forge	61/6
fdry. No. 3	69/–
Lincs. forge	69/–
fdry. No. 3	71/6
E.C. hematite	84/6
W.C. hematite	87/–
Lincs. (at furnaces)—Forge No. 4	63/–
Foundry No. 3	65/–
Basic	63/6
Lancashire (d/d eq. Man.)—Derby forge	65/–
fdry. No. 3	73/6
Northants foundry No. 3	74/6
Dalzell, No. 3	110/–
Summerlee, No. 3	96/6
Glengarnock, No. 3	96/6
Gartsherrie, No. 3	96/6
Monkland No. 3	96/6
Coltness, No. 3	96/6
Shotts, No. 3	96/6

FINISHED IRON & STEEL.

Usual District deliveries for iron; delivered consumers' station for steel.

Iron—	£	s.	d.	£	s.	d.
Bars (cr.)	11	5	0 to 12	10	0	
Angles			12	7	6	
Tees to 3 united ins.			13	2	6	
Nut and bolt			11	0	0	
Hoops	14	0	0 to 15	0	0	
Marked bars (Staffs.) f.o.t.			14	10	0	
Gas strip			12	15	0	
Bolts and nuts ¾ in. × 4 in.			16	15	0	
Steel— Ship plates	8	0	0 to 8	15	0	
Boiler plts.	£11	10	to 12	0	0	
Chequer plts.	£9	15	to 10	5	0	
Angles	£7	5	0 to 8	2	6	
Tees	£8	10	0 to 9	2	6	
Channels	£7	2	6 to 7	12	6	
Joists	£7	5	0 to 8	2	6	
Rounds and Squares 3 in. to 5½ ins.			9	0	0	
Rounds under 3 in. to ⅜ in.			8	15	0	
Flats, over 5 in. wide and up			9	10	0	
Flats, 5in. to 1½in.			8	10	0	
Rails, heavy			8	0	0	
Fishplates			12	10	0	
Hoops (Staffs.)			10	10	0	
Black sheets, 24g.			11	5	0	
Galv. cor. sheets, 24g.			16	5	0	
Galv. fencing wire 8g. plain			14	0	0	
Billets, soft	£6	5	0 to 7	10	0	
Billets, hard			8	12	6	
Sheet bars	£6	5	0 to 6	10	0	
Tin bars d/d	£6	5	0 to 6	10	0	

PHOSPHOR BRONZE.

	Per lb.	basis.
Strip	1	3
Sheet to w.g.	1	3½
Wire	1	3¾
Rods	1	3
Tubes	1	8
Castings	1	2

Delivery 3 cwt. free

10% phos. cop. £40 above B.S.

15% phos. cop. £50 above B.S.

Phosphor tin (5%) £30 above price of English ingots.

C. Clifford & Son, Limited.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	9d. to 1/3
Rolled—To 9 in. wide	1/3 to 1/9
To 12 in. wide	1/3½ to 1/9½
To 15 in. wide	1/3½ to 1/9½
To 18 in. wide	1/4 to 1/10
To 21 in. wide	1/4½ to 1/10½
To 25 in. wide	1/5 to 1/11
Ingots for spoons and forks	9d. to 1/5½
Ingots rolled to spoon size	1/– to 1/8½

Wire round—3/0 to 10 G. 1/6½ to 2/1½ with extras according to gauge.

AMERICAN IRON & STEEL.

At Pittsburgh unless otherwise stated.	Dols.
No. 2X foundry, Phila.	22.26
No. 2 foundry, Valley	20.76
No. 2 foundry, Birm.	18.50
Basic	20.26
Bessemer	21.26
Malleable	20.76
Grey forge	20.26
Ferro-mang. 80% d/d	115.00
Bess. rails, h'y, at mill	43.00
O.-h. rails, h'y at mill	43.00
Bess billets	35.00
O.-h. billets	35.00
O.-h. sheet bars	35.00
Wire rods	45.00
	Cents.
Iron bars, Phila.	2.12
Steel bars	2.00
Tank plates	1.80
Beams, etc.	1.90
Skelp, grooved steel	1.90
Skelp, sheared steel	1.90
Steel hoops	2.40
Sheets, black, No. 28	3.10
Sheets, galv., No. 28	4.20
Sheets, blue an'l'd, 9 & 10	2.25
Wire nails	2.65
Plain wire	2.50
Barbed wire, galv.	3.35
Tinplate, 100 lb. box	$5.50

COKE (at ovens).

Welsh foundry	37/6
furnace	27/6
Durham & North. foundry	35/–
furnace	14/–
Other Districts, foundry	35/–
furnace	11/6 to 13/6

TINPLATES.

f.o.b. Bristol Channel ports.

I.C. Cokes,	20×14, box	19/7½
	28×20, „	39/3
	20×10, „	29/3
	18¾×14, „	20/6
C.W.	20×14. „	17/10½
	28×20, „	35/10½
	20×10,	25/3
	18¾×14, „	18/7½

Terneplates 28×20, 36/4½ per box basis f.o.b.

SWEDISH IRON.

Bars, hammered	£19/0 to £20/0
Rolled Ord.	£16/0/0 to £16/10/0
Nail rods	£16 5 0 to £16 15 0
Keg. steel nom.	£33 to £35
Faggot steel nom.	£22 to £25
Blooms, according to quality	£10 to £14
Pig-iron	£6 15 0 to £7 0 0

all f.o.b. Gothenburg.

TUBES.

	Up to and incl. 6 in.	
Gas	55%	Tube prices are now free.
Water	50%	
Steam	45%	

DAILY FLUCTUATIONS.

Standard Copper (Cash).

	£	s.	d.	
Oct. 8	61	5	0	dec. 2/6
„ 9	62	2	6	inc. 17/6
„ 12	62	7	6	„ 5/–
„ 13	62	10	0	„ 2/6
„ 14	62	7	6	dec. 2/6

Electrolytic Copper.

	£	s.	d.	
Oct. 8	66	15	0	inc. 2/6
„ 9	67	15	0	„ 20/–
„ 12	68	0	0	„ 5/–
„ 13	68	2	6	„ 2/6
„ 14	68	0	0	dec. 2/6

Standard Tin (Cash).

	£	s.	d.	
Oct. 8	271	0	0	No change
„ 9	274	2	6	inc. 62/6
„ 12	274	17	6	„ 15/–
„ 13	277	5	0	„ 47/6
„ 14	279	0	0	„ 35/–

Tin (English ingots).

	£	s.	d.	
Oct. 8	271	0	0	No change
„ 9	274	0	0	inc. 60/–
„ 12	275	0	0	„ 20/–
„ 13	277	5	0	„ 45/–
„ 14	279	0	0	„ 35/–

Zinc Sheets (English).

	£	s.	d.	
Oct. 8	44	0	0	No change
„ 9	45	0	0	inc. 20/–
„ 12	45	0	0	No change
„ 13	45	0	0	„ „
„ 14	45	0	0	„ „

Spelter (ordinary).

	£	s.	d.	
Oct. 8	39	2	6	dec. 8/9
„ 9	39	10	0	inc. 7/6
„ 12	39	17	6	„ 7/6
„ 13	40	0	0	„ 2/6
„ 14	40	8	9	„ 8/9

Lead (English).

	£	s.	d.	
Oct. 8	40	5	0	No change
„ 9	41	15	0	inc. 10/–
„ 12	40	15	0	No change
„ 13	40	5	0	dec. 10/–
„ 14	40	5	0	No change

Belgium.—Iron Ore Production, Imports and Exports.

Year.	Output of native iron ore.	Total imports.	Total exports	Home consumption.
	Tons.	Tons.	Tons.	Tons.
1890 ..	184,000	1,742,000	292,000	1,634,000
1891 ..	217,000	1,622,000	302,000	1,537,000
1892 ..	223,000	1,794,000	363,000	1,654,000
1893 ..	252,000	1,837,000	348,000	1,741,000
1894 ..	328,000	2,090,000	432,000	1,986,000
1895 ..	330,000	2,062,000	555,000	1,837,000
1896 ..	325,000	2,306,000	653,000	1,978,000
1897 ..	265,000	2,779,000	680,000	2,364,000
1898 ..	230,000	2,480,000	643,000	2,067,000
1899 ..	211,000	2,860,000	594,000	2,477,000
1900 ..	255,000	2,794,000	720,000	2,329,000
1901 ..	223,000	1,923,000	505,000	1,641,000
1902 ..	163,000	2,677,000	531,000	2,309,000
1903 ..	181,000	3,183,000	572,000	2,792,000
1904 ..	204,000	3,440,000	568,000	3,076,000
1905 ..	175,000	3,508,000	615,000	3,068,000
1906 ..	228,000	3,683,000	620,000	3,291,000
1907 ..	311,000	3,784,000	737,000	3,358,000
1908 ..	193,000	3,486,000	636,000	3,043,000
1909 ..	203,000	4,438,000	589,000	4,052,000
1910 ..	121,000	5,352,000	837,000	4,636,000
1911 ..	150,500	5,678,000	522,000	5,306,500
1912 ..	167,370	6,415,000	688,290	6,311,000
1913 ..	148,000	7,085,000	728,000	6,505,000
1914 ..	81,000	—	—	—
1915 ..	4,600	—	—	—
1916 ..	29,900	—	—	—
1917 ..	16,700	—	—	—
1918 ..	490	—	—	—
1919 ..	4,700	713,000	15,000	702,700
1920 ..	5,100	2,380,000	150,000	2,235,100
1921 ..	58,500	1,653,000	173,000	1,538,500
1922* ..	62,000	3,500,000	772,000	2,790,000
1923 ..	85,600	6,512,000	726,700	5,870,900
1924 ..	—	8,913,000	1,473,000	—

All figures are in English tons.
* Imports and exports include Luxemburgh from and including May, 1922.

Belgium.—Production of Finished Iron and Steel.

Year.	Finished iron	Total of finished steel.	Total of finished iron and steel.
	Metric tons.	Metric tons.	Metric tons
1901	380,560	489,640	870,200
1902	381,630	725,320	1,106,950
1903	392,380	914,250	1,306,630
1904	355,190	1,023,560	1,378,750
1905	377,620	1,091,400	1,469,020
1906	358,250	1,164,740	1,522,990
1907	358,500	1,216,690	1,575,190
1908	306,650	989,400	1,296,050
1909	304,910	1,264,650	1,569,560
1910	299,500	1,534,550	1,834,050
1911	290,270	1,654,960	1,945,230
1912	334,750	1,903,270	2,238,020
1913	304,000	1,858,000	2,162,000
1914	151,110	1,088,000	—
1915	28,090	136,000	—
1916	101,300	12,200	—
1917	51,620	24,000	—
1918	51,060	16,000	—
1919	68,800	342,100	410,900
1920	161,850	1,132,000	1,293,850
1921	159,270	837,000	996,270
1922	174,180	1,347,000	1,521,180
1923	210,000	1,770,000	1,980,000

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SMALL ADVERTISEMENTS.

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SITUATIONS VACANT AND WANTED.

FOUNDRY FOREMAN, age 45, requires position; practical knowledge of Dry and Green Sand Castings; also experienced with Jar-ram and Squeezing Machines.—Box W. A. G., Offices of The Foundry Trade Journal, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2

FOREMAN MOULDER, Brass or Iron, seeks position; age 43 years; 15 years' experience as Foreman Moulder; Marine, Oil Engines, Hydraulic, Textile, Railroad, Crane and Mining Work; willing to go anywhere.—Box 468, Offices of The Foundry Trade Journal, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

FOUNDRY FOREMAN, disengaged, desires position; 22 years' experience; Engineering and Jobbing work; mix Grey Iron, Semi-steel, Non-ferrous Metals by analysis; can get maximum production and take charge of pattern shop.—Box 472, Offices of The Foundry Trade Journal, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

FOREMAN PATTERNMAKER desires a position with a progressive firm; first-rate experience in modern Machine Moulding; thoroughly well-versed in Wood and Metal Patterns; can lay out work to the best advantage for production purposes; has had good Electrical and General Engineering and Light Casting experience; willing to consider any reasonable proposition; can give good references if required.—Apply Box 500, Offices of The Foundry Trade Journal, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

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EXPERIENCED ROLL FOUNDRY FOREMAN, in South Staffordshire district, to take complete charge of Roll Making, including Mixtures, Melting, Moulding and Casting of Chilled and Grain Rolls; must be qualified man, with good previous experience. References and wages required, experience and age to be stated.—Box 494, Offices of The Foundry Trade Journal, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

QUALIFIED FOUNDRY METALLURGIST, to control Chilled and Grain Roll Manufacture; must have good previous experience of all branches, including Mixture and Furnace Control. Details of previous experience, age and salary to be given.—Box 496, Offices of The Foundry Trade Journal, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

ASSISTANT CHEMIST wanted for large Ironworks in Midlands; young, with three or four years' experience in Foundry Laboratory. State qualifications, experience, age and salary required.—Apply Box 498, Offices of The Foundry Trade Journal, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

FOUNDRY WORKS FOREMAN WANTED for die casting foundry, London. Reply, with details of experience and salary required, Box 502, Offices of The Foundry Trade Journal, Bessemer House, 5 Duke Street, Adelphi, Strand, London W.C.2.

PATENTS & TRADE MARKS.

PATENT YOUR INVENTIONS, Trade-mark your Goods. Advice, Handbook and Cons. free.—B. T. King, C.I.M.E. (Regd. Pat. Agent, G.B., U.S.A., and Can.), 146a, Queen Victoria Street, E.C.4. 38 years' refs. 'Phone 682 Central.

PROPERTY.

FOUNDRY AND ENGINEERING WORKS FOR SALE, as a going concern; freehold; low rates; present output 30 tons weekly of speciality and general Iron Castings; unique opportunity for good return on capital; present owners retiring from the business, but consider reinvesting capital.—For particulars write Box 470, Offices of The Foundry Trade Journal, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

MACHINERY.

FOR SALE.—Lathes, Motor Drills, Flexible Shafting and Patent Rights.—Particulars, apply Box 478, Offices of The Foundry Trade Journal, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

FOR SALE.—20-in. and 24-in. Hall's Invincible Sand Mixers; the original and best machine in the market for mixing old and new Foundry Sand, Coal Dust, etc.—Apply Penney & Porter (Eng.), Ltd., Lincoln.

SAND MIXERS.—New and secondhand. Ask us to quote.—W. Brealey & Company, Ltd., Russell Street, Sheffield.

MACHINERY, PLANT, &c.

No. 3B. BROACHING MACHINE, by J. N. Lapointe & Company; capacity side of broach, 3¼in.; stroke, 56 in.

28 in. stroke HEAVY DUTY PILLAR TYPE SHAPING MACHINE; T-slotted table, 18 in. x 28 in. x 18 in. deep.

4 ft. 6 in. RADIAL DRILLING MACHINE, by Fosdick Machine Company; low base; spindle, 3⅜ in. dia.

SET OF GUILLOTINE SHEARS, by J. Hand & Sons; style C.D.; 36 in. blade to cut 3/16 in. thick.

FOUR LANCASHIRE BOILERS, 30 ft. x 8 ft.; reinsure 150 lbs. pressure.

DOUBLE FURNACE ECONOMIC BOILER, 14 ft. x 8 ft.; reinsure 160 lbs. pressure.

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MISCELLANEOUS.

PATTERNS.—Inquiries solicited; quotations by return; shop equipped with modern machinery; quick delivery.—Cleghorn & Company, Midland Pattern Works, Spring Gardens, Worcester. Phone 264.

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2 Ton EVANS	£28
5 Ton STEVENSON	£38

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